Heat Structure (HS) Package
Users' Guide

The MELCOR Heat Structure (HS) package calculates heat conduction within an intact, solid structure and energy transfer across its boundary surfaces into control volumes. The modeling capabilities of heat structures are general and can include pressure vessel internals and walls, containment structures and walls, fuel rods with nuclear or electrical heating, steam generator tubes, piping walls, etc.

This User's Guide provides basic information needed to run the HS package with the rest of MELCOR, including a short discussion of the nodalization scheme and calculational framework of the package and a detailed explanation of the user input and package output for MELGEN and MELCOR. Required and optional input, sensitivity coefficients, control function arguments, plot variables, and error messages are all covered.

More detailed information on the models and numerical solutions employed by the HS package can be found in the HS Package Reference Manual.

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1. Introduction

The Heat Structure (HS) package calculates heat conduction within an intact, solid structure and energy transfer across its boundary surfaces into control volumes. This document is the users' guide for the HS package. It provides information that is necessary to execute the HS package with other packages in the MELCOR Code System.

This section describes the modeling of a heat structure in the MELCOR Code System and provides a brief discussion of the calculation procedure which is used to obtain the temperature distribution for each heat structure and to calculate its interactions with structures in other packages.

A heat structure is an intact, solid structure which is represented by one-dimensional heat conduction with specified boundary conditions at each of its two boundary surfaces. The modeling capabilities of heat structures are general and can include pressure vessel internals and walls, containment structures and walls, fuel rods with nuclear or electrical heating, steam generator tubes, piping walls, etc. Special logic also permits the representation of cylindrical ice columns to model PWR ice condensers.

Figure 1.1 illustrates a heat structure in a control volume. The heat structure is inclined at some angle with respect to the vertical and is partially immersed in a pool. Although the geometry shown here is rectangular, a heat structure may have a rectangular, cylindrical, spherical, or hemispherical geometry.

The heat structure in Figure 1.1 is nodalized with *N* temperature nodes. The nodalization is specified by user input and may be nonuniform, i.e. the distance between temperature nodes need not be the same. Node *1* is the temperature node at the left boundary surface for a rectangular geometry or at the inside boundary surface for a cylindrical, spherical, or hemispherical geometry. Node *N* is the temperature node at the right boundary surface for a rectangular geometry or at the outside boundary surface for the other geometries.

The region between two adjacent temperature nodes is called a mesh interval. Each mesh interval may contain a different material. The name of the material in each mesh interval must be specified by user input. The Material Properties (MP) package provides thermal properties for each material through an interface with the HS package. See the MP Package Users' Guide for details on the default materials and the input which is required for new materials.

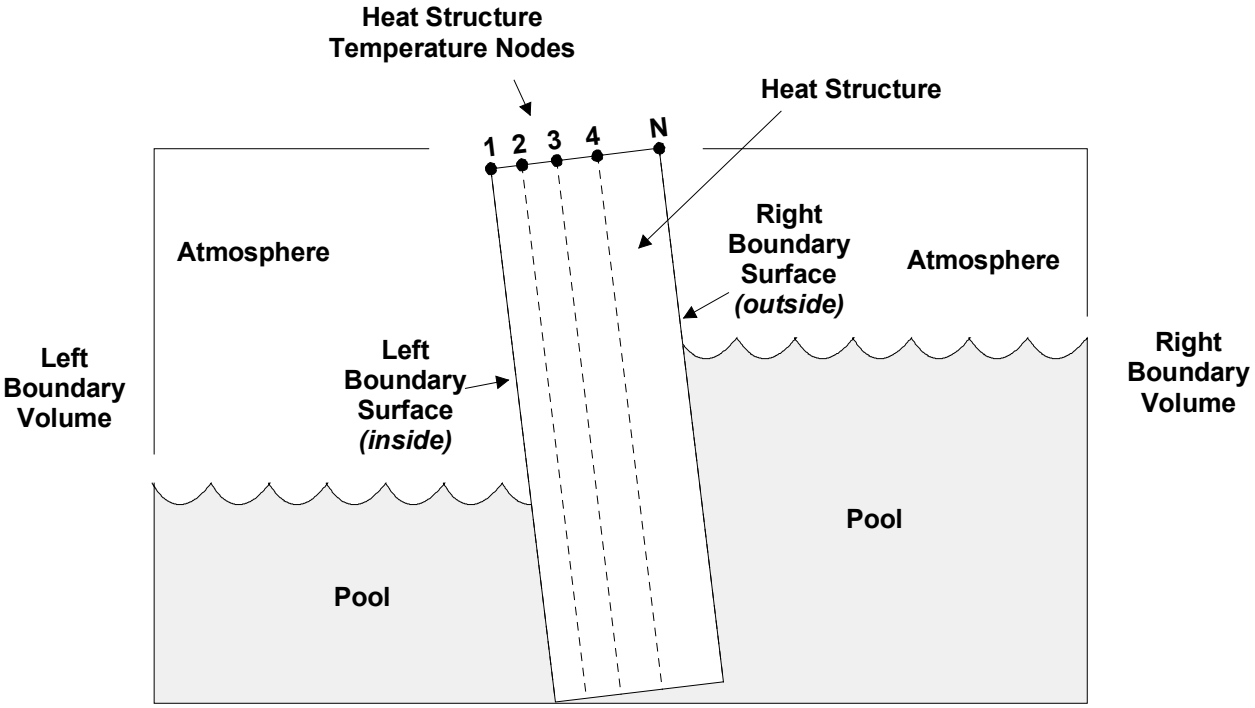

Figure 1.1 Heat Structure in a Control Volume

A pertinent issue for the user of the HS package concerns how finely a heat structure should be nodalized. While no definitive nodalization study is known to exist, the following considerations are useful in resolving this issue*. The mesh interval at a surface should be small enough to accurately respond to changes in the temperature of its boundary volume over a computational cycle. Accurate response is important for correctly calculating energy transfer, condensation-evaporation phenomena, and radionuclide deposition-resuspension. However, the surface mesh interval should not be so small as to encourage temperature oscillations about the boundary volume temperature. Therefore, it is recommended that the size of the surface mesh interval be no smaller than the thermal-diffusion length L_D. That is, ensure that

$$\Delta X_{surf} \geq L_D = \sqrt{4\, k\, \Delta t_{\max} / C_p}$$

where

* L.N. Kmetyk, MELCOR Assessment: Gedanken Problems, Volume 1, SAND92-0762, Sandia National Laboratories, Albuquerque, NM (January 1993).

k = thermal conductivity of material in surface mesh interval,

Δt_{max} = maximum computational timestep, and

C_p = volumetric heat capacity (product of density and heat capacity) of material in surface mesh interval.

If this length is greater than the thickness of the heat structure in the direction of energy flow, two temperature nodes are recommended. Otherwise, to minimize the number of temperature nodes, the length of adjacent mesh intervals should increase toward the interior of the heat structure. However, to maintain accuracy while increasing the distance between temperature nodes, it is recommended that the length of adjacent mesh intervals increase by no more than a factor of two within the same material and the length of adjacent mesh intervals be the same at the boundary of dissimilar materials.

Warning !!

If the length of the mesh interval at a surface is less than about half the thermal diffusion length, oscillations in the surface temperatures may occur. However, these oscillations are bounded and usually are damped out in a few computational cycles if the boundary conditions do not change much. To mitigate these oscillations, the current HS package utilizes a fully implicit numerical method rather than the Crank-Nicolson method used in earlier versions.

An internal power source may be specified for a heat structure. Its spatial dependence is specified by user input and may vary for each mesh interval. Its time dependence is given by a user-specified tabular function or control function.

Each heat structure has two boundary surfaces—left and right for rectangular geometries or inside and outside for cylindrical, spherical, or hemispherical geometries. At each boundary surface one of the following boundary conditions is specified:

(1) symmetry (adiabatic),

(2) convective with calculated heat transfer coefficient,

(3) convective with calculated heat transfer coefficient and a specified surface power source function,

(4) convective with specified heat transfer coefficient function,

(5) specified surface temperature function, and

(6) specified surface heat flux function.

If a convective boundary condition is selected for a boundary surface, a control volume must be specified as its boundary volume. No boundary volume is permitted for a symmetry boundary condition or a specified surface temperature boundary condition, and a boundary volume is a user option for the specified heat flux boundary condition. The Control Volume Hydrodynamics (CVH) Package Reference Manual provides information on control volume modeling.

If a boundary volume is specified for a surface, then some additional data are required through user input. For each boundary surface with a boundary volume, these data include:

(1) surface area,

(2) characteristic length (the dimension used in calculating the Reynolds, Grashof, Nusselt, and Sherwood numbers),

(3) axial length (length of structure along boundary surface, used to determine pool fraction),

(4) type of flow over the surface (internal or external; used in calculating the Nusselt number), and

(5) critical pool fractions for pool and atmosphere heat transfer.

The pool fraction of a heat structure boundary surface is the fraction of its surface area in the pool of its boundary volume. The critical value for the pool is the minimum value of the pool fraction for which heat transfer to the pool is calculated. The critical value for the atmosphere is the maximum value of the pool fraction for which heat transfer to the atmosphere and mass transfer at the surface are calculated.

The critical pool fractions provide the user with flexibility for calculating heat transfer at the surface of a heat structure. The user may elect to turn off the calculation of pool or atmosphere heat transfer by appropriate specification of these fractions. Turning off the calculation of pool heat transfer would be useful, for example, in a situation where a heat structure is partially immersed in a pool whose temperature is considerably less than the temperature of the atmosphere. The situation of high pool-atmosphere temperature differences could be calculated by the CVH package with its nonequilibrium thermodynamics option. In this situation, the heat transfer near the pool-atmosphere interface is significant and axial conduction in this region of the heat structure is quite important. The HS package will calculate large energy transfers from the atmosphere to the pool under these conditions, since it calculates one-dimensional internal conduction and boundary conditions using a weighting of pool and atmosphere temperatures and heat transfer coefficients. If during a calculation large temperature differences between the pool and atmosphere are expected or axial conduction is expected to be important, the user should either subdivide a heat structure into structures of acceptable axial dimensions or turn off pool heat transfer by setting the critical pool fraction for pool heat transfer to 1.0.

If a convective boundary condition with calculated heat transfer coefficients is specified, then an extensive set of correlations is available for calculating natural or forced convection to the pool and atmosphere. Pool boiling heat transfer is calculated if the temperature of a heat structure surface is above the boundary volume saturation temperature by using correlations for nucleate boiling, critical heat flux, film boiling, and transition boiling.

Radiation heat transfer from a heat structure surface to the boundary volume pool is calculated during stable film and transition boiling. Radiation heat transfer can also be specified between a heat structure surface and the boundary volume atmosphere. Two options, an equivalent band model and a gray gas model, are currently available. Radiation heat transfer between user-specified pairs of heat structure surfaces may also be modeled.

Mass transfer between a heat structure surface and the boundary volume atmosphere is modeled using correlations or expressions for calculating mass flux. Models include condensation in a pure steam environment, condensation and evaporation in the presence of noncondensibles, and flashing in any environment. Liquid films on heat structure surfaces are also modeled so that condensate transferred from the boundary volume atmosphere and liquid deposited by other packages can be treated. Mass transfer affects the temperature distribution within a heat structure by its energy flux at the surface. When mass transfer occurs at a structure surface, an equation for the surface temperature of the resulting liquid film including the energy flux due to mass transfer is included in the set of conduction (temperature) equations for the structure.

A film-tracking model is available to treat film flow between structures. The user invokes this model by specifying one or more network(s) of connected structures. The model uses a correlation for film thickness as a function of film flow and the conservation of mass to determine the film thickness and total rate of drainage from each structure in the network. The total drainage from each structure is then partitioned among three possible destination types specified by the user for each structure. A user-specified fraction of the total drainage may be directed to one or more other structure surfaces in the network; a user-specified fraction may "rain" from the surface via a user-specified transfer process to the MELCOR Spray package; and the remainder of the total drainage (one minus the sum of all the user-specified fractions listed above) is directed to the CVH pool component of the control volume associated with the structure surface (this is the only destination for drainage from surfaces which are not included in film-tracking networks). The model also allows the user to specify external water sources for any structure through tabular function or control function input. The model is primarily intended to treat the passive containment cooling systems proposed for ALWRs, but it may also be used to track film flow in steam generators, etc.

Finite-difference equations are used to advance the temperature distribution of a heat structure in time during MELCOR execution or to obtain its steady-state temperature distribution during MELGEN execution if specified by user input. These equations are obtained from an integral form of the one-dimensional heat conduction equation and boundary condition equations using a fully implicit numerical method. The finite-difference

approximation is a tridiagonal system of N (N + 1 or N + 2 if there is a liquid film on one or both surfaces of the structure) equations for a heat structure with N (or N + 1 or N + 2) temperature nodes. The solution of this system is obtained using the standard solution algorithm for a tridiagonal system of linear equations. The procedure is iterative because the coefficients are functions of temperature and must be updated between iterations.

A degassing model is provided for the release of gases from materials which are contained in heat structure mesh intervals. Input may be provided, for example, to represent the release of water vapor or carbon dioxide from concrete as its temperature increases. The following information must be input by the user for each gas source in the degassing model:

(1) heat structure surface from which the gas is released,

(2) number of mesh intervals over which the source is distributed, and

(3) name of gas which is released.

Each gas source is characterized by the following information which is provided by user input:

(1) density,

(2) heat of reaction, and

(3) boundaries of temperature range for the release of gas.

The mass of gas that is available for release is the source density times the volume of the mesh intervals over which the source is distributed. The HS package calculates a constant gas release rate over the degassing temperature range and modifies thermal properties over this range to account for the energy which is required for gas production and release. If the initial temperature of the structure exceeds the lower boundary of the degassing temperature range, MELGEN issues a warning message to inform the user that the gas which would have been released below the initial temperature will be ignored and is unavailable for release.

A special application of the degassing model can be used to model ice condensers. In this application the user defines a vertical cylinder with an adiabatic inner boundary and an associated "gas" source that releases liquid water into the pool associated with the outer radial boundary volume. The lower value of the degassing temperature range should be close to but greater than the freezing point of water (273.15 K) to avoid problems with the limits of the tabular functions in the MELCOR material properties libraries. The upper value of the degassing temperature range should be about 373 K to simulate sensible heating of the melted ice by counter-flowing steam. The heat of reaction should include the sensible heating of both the subcooled ice (from its actual temperature) and melted ice in

addition to the latent heat of fusion of water. The gas source density is the density of liquid water. Furthermore, the user is required to specify an initial temperature for the ice, and this temperature should coincide with the lower limit of the degassing range (274 K). The ice condenser modeling logic is activated by including a special keyword in the user input for the outer radial boundary of the cylindrical heat structure (Record HSCCCCC600).

This users' guide contains eight additional sections. Section 2 describes the user input that is required for utilizing this package in MELGEN and MELCOR execution. The sensitivity coefficients and their default values are given in Section 3. Section 4 lists and briefly describes the plot variables and control function arguments which are available in the HS package. Section 5 provides some example input that illustrates the use of this package. Printed output is discussed in Section 6. Section 7 lists the diagnostics and error messages which are provided by this package.

2. Input Requirements

This section provides the input requirements for the MELCOR HS package, including a short description of the input quantities and their units and default values, if any. Further description of the input variables and their use in the models can be found in the HS Package Reference Manual.

2.1 MELGEN User Input

This section contains a detailed description of the MELGEN user input for the HS package. Input record descriptions are found as follows:

Section 2.1.1 Heat Structure input records
Section 2.1.2 Gas Source input records
Section 2.1.3 Film-tracking input records

2.1.1 MELGEN Input for Heat Structures

Input data for heat structures are entered on records with identifiers of the form

HSCCCCCXNN

where

HS	indicates that the record is a Heat Structure record
CCCCC	is the numerical identifier for the heat structure (00000-99999)
X	is the record type
NN	is the record number for record type X

The following input records are required to specify a heat structure. Unless otherwise stated, field variables beginning with I through N are integers and those beginning with A through H or O through Z are real numbers. A complete set of input records must be supplied for each heat structure.

HSCCCCC000 – General Heat Structure Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Required

This record specifies the existence of a heat structure whose numerical identifier is CCCCC.

(1) NP - Number of temperature nodes. This value must be greater than 1 but less than 100.
(type = integer, default = none, units = none)

(2) IGEOM - Indicator for type of geometry.

= 1 rectangular geometry
= 2 cylindrical geometry
= 3 spherical geometry
= 4 hemispherical geometry of the bottom half of a sphere
= 5 hemispherical geometry of the top half of a sphere.
No other values are permitted for this field.
(type = integer, default = none, units = none)

(3) ISS - Steady-state initialization flag. If 0 or positive, or if field 3 is omitted, a steady-state initialization calculation is performed for Heat Structure CCCCC. If a negative value is input, a steady-state initialization calculation is not performed and the initial temperature distribution is input on the HSCCCCC8XX records. The default is that a steady-state initialization will be performed.
(type = integer, default = 0, units = none)

Node 1 is the temperature node at the left boundary for a rectangular geometry or the inside boundary for a cylindrical, spherical, or hemispherical geometry; Node NP is the temperature node at the right boundary for a rectangular geometry or the outside boundary for a cylindrical, spherical, or hemispherical geometry.

HSCCCCC001 – Heat Structure Name

00000 ≤CCCCC ≤ 99999, CCCCC is the heat structure number.
Optional

(1) HSNAME - Name of heat structure. This field may contain no more than 16 characters and imbedded blanks.
(type = character*16, default = none)

If this record is not present, 16 blanks will be stored as the name of Heat Structure CCCCC.

HSCCCCC002 – Heat Structure Elevation and Orientation Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Required

(1) HSALT - Elevation parameter. This value is the elevation of the lowest point on Heat Structure CCCCC. This parameter must satisfy the condition that each boundary surface of this heat structure is contained within its boundary volume.
(type = real, default = none, units = m)

(2) ALPHA - Orientation parameter.

Rectangular geometries: the absolute value of ALPHA is the cosine of the acute angle α between a vertical line and the heat structure surface (see Figure 1.1).

ALPHA = 1:	vertical surface
ALPHA = 0:	horizontal surface with left-hand side on the bottom
0 < ALPHA < 1:	slanted surface with left-hand side on the bottom
ALPHA = -10^{-7}:	horizontal surface with the right-hand side on the bottom
-1 < ALPHA < -10^{-6}:	slanted surface with right-hand side on the bottom

Cylindrical geometries: the absolute value of ALPHA is the cosine of the acute angle between a vertical line and the axis of this heat structure. Only the absolute value is used for cylindrical geometries.

Spherical or hemispherical geometries: ALPHA has no meaning and does not need to be entered.

For rectangular and cylindrical geometries, ALPHA must be greater than or equal to - 1.0 and less than or equal to 1.0.
(type = real, default = none, units = none)

If only one field is present on this record, it will be interpreted as HSALT. In this situation, ALPHA will be set equal to 1.0, which corresponds to a vertically oriented heat structure.

NOTE on FLOORS and CEILINGS

In associating horizontal rectangular heat structures with CVH control volumes, the upper surface of the structure should be thought of as a floor for the volume. Therefore, for a heat structure of thickness DELT and ALPHA = 0, HSALT + DELT should be greater than or equal to the lowest elevation in the CVH volume-altitude table for that volume. In this case the right-hand side of the structure is the floor of the CVH volume and the CVH volume number is entered in the IBVR field of Record HSCCCCC600.

If ALPHA = -10^{-7} for the same heat structure, then the description is the same except that the left- and right-hand sides are reversed. The right-hand side is on the bottom and the floor is the left-hand side. The CVH volume number is entered in the IBVL field of Record HSCCCCC400.

The same convention applies to ceilings of control volumes, which should be thought of as the lower surface of a horizontal heat structure.

HSCCCCC003 – Heat Structure Multiplicity
00000 ≤CCCCC ≤ 99999, CCCCC is the heat structure number.
Optional

(1) HSMULT - Multiplicity of heat structure. This value is the number of heat structures in this problem that are identical to Heat Structure CCCCC.
(type = real, default = 1.0, units = none)

HSCCCCC004 – Boundary Fluid Temperature Option
00000 ≤CCCCC ≤ 99999, CCCCC is the heat structure number.
Optional (but generally required for COR radial boundary heat structures; see the COR Package Users' Guide and the descriptions of input records COR00006 and CORZjj02)

This record provides the user the option of which bulk fluid temperature to use on each side in the heat transfer calculations for the specified heat structure.

(1) IOPTL - Option for left (inside) surface of the heat structure.

< 0 Use control function -IOPTL for boundary fluid temperature on the left-hand side.

= 0 Use bulk fluid temperature in left boundary CVH volume (either pool or atmosphere depending on liquid level) for boundary fluid temperature on the left-hand side.

> 0 Use fluid temperature calculated by COR package dT/dz model for core cell IOPTL for boundary fluid temperature on the left-hand side.
(type = integer, default = 0, units = none)

(2) IOPTR - Option for right (outside) surface of the heat structure.

< 0 Use control function -IOPTR for boundary fluid temperature on the right-hand side.

= 0 Use bulk fluid temperature in right boundary CVH volume (either pool or atmosphere depending on liquid level) for boundary fluid temperature on the right-hand side.

No core cell input is allowed for the right-hand surface.
(type = integer, default = 0, units = none)

HSCCCCC100 – Temperature Node Location Data

00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Required

(1) NODLOC - Indicator for location of temperature node location data. If negative, all temperature node location data must be entered for Heat Structure CCCCC on the HSCCCCC1NN records. If a nonnegative integer MMMMM, these data are obtained from the HSMMMMM1NN records for Heat Structure MMMMM, which must exist.
(type = integer, default = none, units = none)

(2) IFRMAT - Format flag for temperature node location data. This value indicates the format for specification of data on the HSCCCCC1NN records.

= 1 Each pair of data on each of these records is interpreted as the location of a temperature node and the number of this node. The intermediate nodes are equally spaced between specified node locations.

= 2 Each pair of data on each of these records is interpreted as a length and the number of consecutive mesh intervals with this length.
No other values are permitted for this field.
(type = integer, default = none, units = none)

(3) XI - Left (inside) boundary location. This value gives the location of the temperature node at the left (inside) boundary surface of this heat structure. XI must be greater than or equal to zero.

Rectangular geometries: XI is relative to any origin.
Cylindrical geometries: XI is relative to the axis of the cylinder.
Spherical geometries: XI is relative to the center of the sphere.
Hemispherical geometries: XI is relative to the center of the sphere which contains the hemisphere.
(type = real, default = none, units = m)

If XI is zero, then either the geometry of this heat structure must be rectangular (IGEOM = 1 on Record HSCCCCC000) or a symmetry boundary condition must be applied to the left boundary surface (IBCL = 0 on Record HSCCCCC400).

HSCCCCC1NN – Temperature Node Data
$00000 \leq$ CCCCC ≤ 99999, CCCCC is the heat structure number.
$01 \leq$ NN ≤ 99, NN is the sequence number

These record are required if NODLOC on Record HSCCCCC100 is negative. The format of each record is given in the description of Record HSCCCCC100 and the location of Node 1 is known from XI on Record HSCCCCC100. Two fields per record are entered on the HSCCCCC1NN records until the locations of all remaining temperature nodes for Heat Structure CCCCC are specified.

(1) XVALUE - Location of temperature node (IFRMAT = 1)
Length of mesh interval (IFRMAT = 2)
(type = real, default = none, units = m)

(2) NXVALU - Number of temperature node which has location XVALUE (IFRMAT = 1)
Number of consecutive mesh intervals with length XVALUE (IFRMAT = 2)
(type = real, default = none, units = m)

The record numbers need not be sequential. However, for IFRMAT = 1, XVALUE and NXVALU must be strictly monotonically increasing functions of the NN in HSCCCCC1NN. For IFRMAT = 2, the location of the temperature nodes will be ordered by the NN in HSCCCCC1NN.

HSCCCCC200 – Location of Material Composition Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Optional

(1) MCDLOC - Indicator for location of material composition data. If negative, the material composition data for Heat Structure CCCCC must be entered on the HSCCCCC2NN records. If a nonnegative integer MMMMM, these data are obtained from the HSMMMMM2NN records for Heat Structure MMMMM, which must exist.
(type = integer, default = none, units = none)

If this record is not present, the data for the material composition of Heat Structure CCCCC must be entered on the HSCCCCC2NN records.

HSCCCCC2NN – Material Composition Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
01 ≤ NN ≤ 99, NN is the sequence number

These records are required if either MCDLOC on Record HSCCCCC200 is negative or Record HSCCCCC200 is omitted. The format is two fields per record until materials in the NP-1 mesh intervals of Heat Structure CCCCC are specified, where NP is given on Record HSCCCCC000.

(1) MATNAM - Name of material in mesh interval N, where N is greater than or equal to 1 and less than NP. This field may be a default material name or a new material name. If it is a new material name, then material property input must be provided. See the Material Properties Package Users' Guide for a list of the default materials and the input which is required to specify a new material. MP gases can not be used here. Any gas must be input as "pseudo-gas" with user definition of appropriate values for density, specific heat capacity, and thermal conductivity.

(type = character*24, default = none)

(2) MSHNUM - Mesh interval, N. If the set of all MSHNUM on these records is ordered, the values of MATNUM for a given value of MSHNUM are applied to all mesh intervals between one greater than the next lower value of MSHNUM and the given value of MSHNUM, inclusive.
(type = integer, default = none, units = none)

Record numbers need not be sequential. However, MSHNUM must be a strictly monotonically increasing function of the NN in HSCCCCC2NN.

HSCCCCC300 – Internal Power Source Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Required

(1) ISRC - Internal power source type. If negative or 0, no internal power source exists for Heat Structure CCCCC. If a positive integer TTT (less than 9000), the power must be entered as a function of time in Tabular Function TTT. For ISRC = 9X…X, the power is given by Control Function X…X, where X…X can have from three to eight digits, including leading zeros. The power obtained from the TF or CF is assumed to be given in watts, W.
(type = integer, default = none, units = none)

(2) NSDLOC - Location of internal power source distribution data. If negative and if ISRC on this record is TTT, the internal power source distribution data for Heat Surface CCCCC must be entered on the HSCCCCC3NN records. If a nonnegative integer MMMMM and if ISRC on this record is positive, these data are found on the HSMMMMM3NN records for Heat Structure MMMMM, which must exist.
(type = integer, default = none, units = none)

(3) VSMULT - Internal source multiplier. This number must be entered if ISRC is TTT. It is the fraction of the power from Tabular Function TTT that is applied to this heat structure.
(type = real, default = none, unites = none)

If ISRC is negative or 0, NSDLOC and VSMULT are ignored and do not need to be entered.

HSCCCCC3NN – Internal Power Source Distribution Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
01 ≤ NN ≤ 99, NN is the sequence number

These records are required if ISRC on Record HSCCCCC300 is positive and NSDLOC on Record HSCCCCC300 is negative. The format is two numbers per record until the relative source distribution data are entered for the NP-1 mesh intervals in Heat Structure CCCCC, where NP is given on Record HSCCCCC000.

(1) QFRCIN - Relative source strength. The source values are relative and can be scaled by any factor. These values will be normalized during input processing and multiplied by the internal source multiplier (VSMULT on Record HSCCCCC300) to provide the fraction of power from the appropriate tabular function that is applied to each mesh interval in Heat Structure CCCCC.
(type = real, default = none, units = none)

(2) MSHNUM - Mesh interval number. If the set of all MSHNUM on these records is ordered, the value of QFRCIN for a given value of MSHNUM is applied to all mesh intervals between one greater than the next lower value of MSHNUM and the given value of MSHNUM, inclusive.
(type = integer, default = none, units = none)

Record numbers need not be sequential. However, MSHNUM must be a strictly monotonically increasing function of the NN in HSCCCCC3NN.

HSCCCCC400 – Left (Inside) Boundary Surface Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Required

(1) IBCL - Boundary condition type. The magnitude of IBCL must be one of the following integers to specify the type of boundary condition that is applied at the left (or inside) boundary surface of Heat Structure CCCCC. If the sign of the flag is negative, mass transfer at this surface is not evaluated.

In the following, XXX (referring to a *Tabular Function*) must consist of <u>exactly three digits</u>, including leading zeros if necessary, while X…X (referring to a *Control Function*) may consist of from <u>three to eight digits</u>, possibly including leading zeros.

= 0 A symmetry (insulated) boundary condition is applied.

= 1 A convective boundary condition is applied with the heat transfer coefficients calculated by the HS package.

= 1XXX A convective boundary condition is applied with the heat transfer coefficients calculated by the HS package. A surface power source, whose power is given as a function of time by Tabular Function XXX, is also applied at this surface. The units of quantities obtained from Tabular Function XXX are assumed to be W.

= 2XXX The temperature of this surface is given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be K.

= 3XXX The heat flux from this surface is given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be W/m^2.

= 4XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

= 5XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of the surface temperature by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

= 6XXX A convective boundary condition is applied with the heat transfer coefficients specified by Control Function X…X. The units of quantities obtained from Control Function XXX are assumed to be $W/m^2 \cdot K$.

= 7XXX A convective boundary condition is applied with the heat transfer coefficients calculated by the HS package. A surface power source, whose power is given by Control Function X…X, is also applied at this surface. The units of quantities obtained from Control Function X…X are assumed to be W.

= 8XXX The temperature of this surface is specified by Control Function X…X. The units of quantities obtained from Control Function X…X are assumed to be K.

= 9XXX The heat flux from this surface is specified by Control Function X…X. The units of quantities obtained from Control Function X…X are assumed to be W/m^2.
(type = integer, default = none, units = none)

For details of the input required for tabular functions, see the Tabular Function Package Users' Guide. If control functions are used to specify boundary conditions with IBCL = 6XXX, 7XXX, 8XXX, or 9XXX, their values must be initialized through their respective CFXXX01 records. For details on control function input, see the Control Function Package Users' Guide.

(2) IBVL - Numerical identifier of boundary volume. This value specifies the control volume which is associated with the left (inside) boundary surface of Heat Structure CCCCC. If this value is negative, no control volume is associated with this surface. All fluid quantities required for the heat transfer coefficient calculations are obtained from the appropriate quantities for the boundary volume specified by this value if it is not negative. It is noted that the control volume and heat structure elevations must be specified so that heat structure clearly is located within the control volume.
(type = integer, default = none, units = none)

(3) IFLOWL - Indicator for type of flow over left (inside) boundary surface of Heat Structure CCCCC. This value is used to determine the type of convective heat transfer correlation to be used in evaluating the heat transfer coefficient on this surface, see Section 2.6.1 of the HS Reference Manual.

= 'INT' internal flow
= 'EXT' external flow

No other values are permitted for this field.
(type = character*3, default = none)

(4) CPFPL - Critical pool fraction for pool. This is the minimum value of the pool fraction such that heat transfer to the pool is calculated at the left (inside) boundary surface of Heat Structure CCCCC. It must be between 0.0 and 1.0, inclusive. See discussion below.
(type = real, default = none, units = none)

(5) CPFAL - Critical pool fraction for atmosphere. This is the maximum value of the pool fraction such that heat and mass transfer to the atmosphere is calculated at the left (inside) boundary surface of Heat Structure CCCCC. It must be between 0.0 and 1.0, inclusive. See discussion below and also see SC4071 for further restrictions on the bounds.
(type = real, default = CPFPL, units = none)

(6) CTDPL - Critical temperature difference for pool heat transfer. If the temperature difference between the structure surface and the pool exceeds this value, then the timestep may be limited in order to ensure both accuracy in the calculated temperature difference and stability in the pool temperature.
(type = real, default = 100., units = K)

(7) CTDAL - Critical temperature difference for atmosphere heat transfer. This value is used in exactly the same way as CTDPL, except it applies to heat transfer from the structure surface to the atmosphere rather than the pool.
(type = real, default = 100., units = K)

(8) XHTFCL - Calculated atmosphere heat transfer scaling factor. Calculated heat transfer coefficients (IBCL = 1, IBCL = 1XXX or IBCL = 7XXX) to the atmosphere are multiplied by this arbitrary scaling factor, which must be nonnegative.
(type = real, default = 1.0, units = none)

(9) XMTFCL - Mass transfer scaling factor. Mass transfer coefficients (IBCL > 0 and IBVL > 0) for the condensation/evaporation of liquid films are multiplied by this arbitrary scaling factor, which must be nonnegative.
(type = real, default = 1.0, units = none)

Control volume assignment (and therefore mass transfer) for adiabatic or specified temperature boundary conditions (IBCL = 0, 2XXX, or 8XXX) is prohibited. For these conditions, IBCL must be less than or equal to zero and fields 2 through 9 are ignored and do not need to be entered. IBVL must be entered for any other boundary condition type.

Mass transfer to a surface with a specified heat flux boundary condition (IBCL = 3XXX or 9XXX) is also prohibited, although the assignment of a control volume in this case is optional. For this condition, IBCL must be negative and IBVL must be entered.

If no control volume is associated with this surface (IBVL < 0), then the boundary condition type must be adiabatic, specified temperature, or specified heat flux (IBCL = 0, 2XXX, 3XXX, 8XXX, or 9XXX). Furthermore, fields 3 through 9 are ignored and do not need to be entered.

For boundary surfaces with specified or calculated heat transfer coefficients (IBCL = 1, 1XXX, 4XXX, 5XXX, 6XXX, or 7XXX), fields 3 and 4 (IFLOWL and CPFPL) are required, although IFLOWL is not used when heat transfer coefficients are specified through 4XXX, 5XXX, or 6XXX.

If the heat flux at both surfaces is specified (IBCL = 0, 3XXX, or 9XXX and IBCR = 0, 3XXX, or 9XXX), then steady-state initialization must not be requested (ISS on Record HSCCCCC000) because a solution is either impossible or arbitrary.

Careful consideration should be given to the selection of values for CPFPL and CPFAL.

If the values of CPFPL and CPFAL are set equal to the same value, heat transfer will occur to either the pool or atmosphere (but not both at the same time) depending upon the value of the pool fraction for the current time.

If CPFPL exceeds CPFAL, there will be no heat transfer to either pool or atmosphere while the value of the pool fraction is between CPFPL and CPFAL.

If CPFAL exceeds CPFPL, there will be heat transfer to both pool and atmosphere while the pool fraction is between CPFPL and CPFAL.

A non-fatal warning message is printed to the output and diagnostic files if the values of CPFPL and CPFAL are not equal.

Refer to the HS Reference Manual for further discussion of the implications of input values for CPFPL and CPFAL. Similar consideration should be given to the inputs for CPFPR and CPFAR which apply to the right boundary surface on Record HSCCCCC600.

HSCCCCC401 – Left (Inside) Boundary Surface Radiation Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Optional

Inclusion of this record enables radiation heat transfer for the left surface.

(1) EMISWL - Wall emissivity of the left surface. A value of 0. turns radiation heat transfer off at this surface. The wall emissivity is constant

for the transient except when a water film is present. In this case, the emissivity of the wall is calculated using a mechanistic model for radiation on film-covered surfaces.
(type = real, default = none, units = none)

(2) RMODL - Radiation model employed. Two options are currently available. The "-" in the following parameters can be replaced by a space if the parameter is enclosed in single quotes. Upper and lower case characters are equivalent.

= equiv-band equivalent band model
= gray-gas-a gray gas model
(type = character*10, default = none)

(3) PATHL - Radiation path length for the left surface.
(type = real, default = none, units = m)

All three parameters must be entered if this record is present. If the record is not included in the input, no radiation heat transfer is calculated for this surface. See the HS Reference Manual for details on the radiation models available.

HSCCCCC500 – Additional Left (Inside) Boundary Surface Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.

This record is required for the left (inside) boundary surface of each specified heat structure unless either (a) a symmetry or specified temperature boundary condition is applied at this surface (IBCL on Record HSCCCCC400 is 0, 2XXX, or 8XXX) or (b) no boundary volume is specified for this surface (IBVL on Record HSCCCCC400 is negative). In either case (a) or (b) these variables are not needed for the calculation.

(1) ASURFL - Area of boundary surface. This value is the area of the left (inside) boundary surface of Heat Structure CCCCC. ASURFL must be strictly positive. This field is ignored for cylindrical or (hemi)spherical geometries.

Rectangular geometries: the area of this surface and the right (outside) boundary surface (ASURFR on Record HSCCCCC700) must be equal.

Cylindrical geometries: the area of this surface will be calculated from the location of the left (inside) temperature node (XI on Record HSCCCCC100) and the axial length of this structure (BNDZL on this record).

Spherical or hemispherical geometries: the area of this surface will be calculated from the location of the left (inside) temperature node (XI on Record HSCCCCC100).
(type = real, default = none, units = m^2)

(2) CLNL - Characteristic length of boundary surface. This value is the dimension that is used to calculate quantities such as the Reynolds, Grashof, Nusselt, and Sherwood numbers. CLNL must be strictly positive.
(type = real, default = none, units = m)

(3) BNDZL - Axial length of boundary surface. This value is the dimension of the left (inside) boundary surface of Heat Structure CCCCC in a direction perpendicular to the direction of energy flow within this heat structure. BNDZL must be strictly positive. This field is ignored for spherical or hemispherical geometries.

Rectangular or cylindrical geometries: The axial length of this surface and the right (outside) boundary surface (BNDZR on Record HSCCCCC700) must be equal.

Spherical or hemispherical geometries: The axial length is calculated from the location of the left (inside) temperature node (XI on Record HSCCCCC100).
(type = real, default = none, units = m)

HSCCCCC600 – Right (Outside) Boundary Surface Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Required

The fields on this record (IBCR, IBVR, IFLOWR, CPFPR, CPFAR, CTDPR, CTDAR, XHTFCR and XMTFCR) correspond to the fields on Record HSCCCCC400 but apply to the right (outside) boundary surface of Heat Structure CCCCC rather than the left (inside) boundary surface. One additional option IFLOWR = 'ICE' is allowed.

The **ice condenser model** is activated by specifying IFLOWR = ICE. In this case the heat structure should be a cylindrical structure with an adiabatic inner boundary. The associated gas source that releases liquid water is connected to the CVH control volume specified by IBVR. See record HSDGCCCCC1. IBCR = 1, CPFAR = 0.5, and CPFPR = 0.5 should be used. An example is shown in Section 5.2.

The initial temperature specified on Record HSCCCCC8XX should be 274K. It is recommended that the value of HTRSRC on record HSDGCCCCC1 be adjusted

accordingly to include the sensible heat required to raise the temperature of the subcooled ice through the melting point to 274K, plus the sensible energy required to raise the released water to the steam saturation temperature.

CAUTION !!

The ice condenser model will malfunction if any part of the ice condenser becomes submerged in the melt water pool in the outer boundary CVH volume. The user must provide sufficient volume below the bottom of the ice condenser structure to accommodate all of the melted ice. Also an initial ice temperature below 273.15K will cause problems in the material properties routines.

HSCCCCC601 – Right (Outside) Boundary Surface Radiation Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Optional

The fields on this record (EMISWR, RMODR, and PATHR) correspond to the fields on Record HSCCCCC401 but apply to the right (outside) boundary surface of Heat Structure CCCCC rather than the left (inside) boundary surface.

HSCCCCC700 – Additional Right (Outside) Boundary Surface Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.

This record is required for the right (outside) boundary surface of each specified heat structure unless either (a) a symmetry boundary condition is applied at this surface (IBCR on Record HSCCCCC600 is 0) or (b) no boundary volume is specified for this surface (IBVR on Record HSCCCCC600 is negative). In either case (a) or (b) these variables are not needed for the calculation.

The fields on this record (ASURFR, CLNR, and BNDZR) correspond to the fields on Record HSCCCCC500 but apply to the right (outside) boundary surface of Heat Structure CCCCC rather than the left (inside) boundary surface. However, in geometries for which the area of this surface is calculated, the location of the right (outside) temperature node is used rather than the location of the left (inside) temperature node).

HSCCCCC800 – Initial Temperature Distribution Location
00000 ≤ CCCCC ≤ 99999, CCCCC is the heat structure number.
Optional

This record and the following one (HSCCCCC800 and HSCCCCC8NN) should not be present if ISS ≥ 0 on Record HSCCCCC000 because a steady-state calculation will be performed to determine the initial temperature distribution. (A warning

message will appear in the MELGEN diagnostics file if these records appear when ISS $\geq$ 0.)

(1) NTDLOC - Indicator for location of initial temperature distribution. If negative, the initial temperature distribution for Heat Structure CCCCC must be entered on the HSCCCCC8NN records. If a nonnegative integer MMMMM, these data are found on the HSMMMMM8NN records for Heat Structure MMMMM, which must exist.
(type = integer, default = none, units = none)

HSCCCCC8NN – Initial Temperature Distribution Data
00000 $\leq$ CCCCC $\leq$ 99999, CCCCC is the heat structure number.
01 $\leq$ NN $\leq$ 99, NN is the sequence number.

These records are required if NTDLOC on Record HSCCCCC800 is negative. The format is two fields per record until temperatures for the NP temperature nodes in Heat Structure CCCCC are specified, where NP is given on Record HSCCCCC000.

(1) TEMPIN - Initial temperature. This temperature must be strictly positive.
(type = real, default = none, units = K)

(2) NODNUM - Temperature node number. If the set of all NODNUM on these records is ordered, the value of TEMPIN for a given value of NODNUM is applied to all temperature nodes between one greater than the next lower value of NODNUM and the given value of NODNUM, inclusive.
(type = integer, default = none, units = none)

Record numbers need not be sequential. However, NODNUM must be a strictly monotonically increasing function of the NN in HSCCCCC8NN.

2.1.2 MELGEN Input for Gas Sources

Input data for gas sources for the HS package degassing model are entered on records with identifiers of the form

HSDGCCCCCN

where

HSDG	indicates that the record is a gas source record
CCCCC	is the numerical indicator for the gas source (00000 – 99999)
N	is the record number

The following input records are required to specify a gas source. Unless otherwise stated, if the field record begins with I through N, it is an integer. Unless otherwise stated, if the field variable begins with A through H or O through Z, it is a real number. A complete set of input records must be supplied for each gas source.

HSDGCCCCC0 – General Gas Source Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the gas source number
Required

(1) ISRCHS - Gas release surface. This value indicates from which heat structure boundary surface gas is released from Source CCCCC. The absolute value of ISRCHS is the number of the heat structure which contains this source. If ISRCHS is negative, gas is released from the left (inside) boundary surface of the heat structure; if positive, gas is released from the right (outside) boundary surface. ISRCHS cannot equal 0 and the absolute value of ISRCHS must be the number of an existing heat structure.
(type = integer, default = none, units = none)

(2) ISDIST - Source distribution. This value is the number of mesh intervals over which Source CCCCC is distributed. ISDIST must be greater than or equal to 1 and less than or equal to the number of mesh intervals in the heat structure which contains this source.
(type = integer, default = none, units = none)

(3) GASNAM - Name of released gas. This is the name of the gas which is released from Source CCCCC. It must be the name of a material that is present in the problem. Valid names are:

POOL	-	Pool liquid water
FOG	-	Atmosphere liquid water
H2O-VAP	-	Atmosphere water vapor
H2	-	Hydrogen
O2	-	Oxygen
CO2	-	Carbon dioxide
CO	-	Carbon monoxide
N2	-	Nitrogen
NO	-	Nitrogen monoxide
N2O	-	Nitrous oxide
NH3	-	Ammonia
C2H2	-	Acetylene
CH4	-	Methane

C2H4	-	Ethylene
GASk	-	User-defined gas (k=A, B, …, J)
SS	-	Steel

The first three are present in all problems. The others must be specified for the problem through Noncondensible Gas (NCG) input. See the NCG Package Users' Guide for details on input for those gases that must be specified.

The SS material type is intended for use in MELCOR calculations where the COR package is employed to model melting of core boundary steel structures. Molten steel is entered into the outer radial ring of the core region at the corresponding elevation. Subsequent relocation of the steel is modeled by the COR package. If COR is not used, the SS source will be ignored.
(type = character*8, default = none)

There are several restrictions concerning the "SS" degassing option. These are listed below:

(1) The structure identified by ISRCHS must have an orientation that is either horizontal (ALPHA = 0.0) or vertical (ALPHA = 1.0) as identified on the corresponding input Record HSCCCCC002. If the structure is not horizontal or vertical, MELGEN processing will terminate.

(2) The structures for which SS degassing is desired must lie either along the core or above the core. If along the core, then a structure must align with one of the COR package axial segments as identified by input record CORRZjj01. Structures are not permitted to span across COR axial segments. If the degassing structure lies above the core, then its lowermost elevation must exceed the uppermost core elevation as modeled by the COR package.

(3) Special restrictions apply to changing "SS" degassing input for MELCOR restarts. See Section 2.2.2.

HSDGCCCCC1 – Gas Source Characterization Data
00000 ≤ CCCCC ≤ 99999, CCCCC is the gas source number
Required

(1) RHOSRC - Density of gas source. This value is the density of Gas Source CCCCC. This density times the volume of the mesh intervals over which it is distributed is the mass of gas that can be released by this source. RHOSRC must be greater than or equal to zero. (type = real, default = none, units = kg/m^3)

(2) HTRSRC - Heat of reaction of gas source. This value is the heat of reaction of Gas Source CCCCC. The volumetric heat capacity is increased by the product of HTRSRC and the density of this source (RHOSRC on this record) divided by the temperature range over which gas is released (TEMPU minus TEMPL on this record) to yield the effective volumetric heat capacity of the material in a mesh interval of a degassing heat structure. HTRSRC must be greater than or equal to zero.
(type = real, default = none, units = J/kg)

(3) TEMPL - Lower temperature for degassing. This value is the lower boundary of the temperature range for the release of gas from Gas Source CCCCC. TEMPL must be greater than zero.
(type = real, default = none, units = K)

(4) TEMPU - Upper temperature for degassing. This value is the upper boundary of the temperature range for the release of gas from Gas Source CCCCC. TEMPU must be greater than TEMPL on this record.
(type = real, default = none, units = K)

The next three variables apply only if an **ice condenser structure** has been defined by inputs on Record HSCCCCC600. See the example in Section 5.2.

(5) HTCICE - Ice condenser Nusselt number multiplier. This value is a multiplier for calculated heat and mass transfer coefficients.
(type = real, default = none, units = none)

(6) RNDICE - Ice condenser RN deposition surface area enhancement factor. The surface area used in the RN deposition model is equal to the calculated ice surface area (defined below) plus the value of the original ice surface area multiplied by this enhancement factor. A nonzero value for RNDICE is used to account for heat transfer and radionuclide deposition to the wire baskets normally found in ice condensers that remain in place after the ice has melted.
(type = real, default = none, units = none)

(7) EXPICE - Ice condenser surface area exponent. The calculated heat and mass transfer surface area of the ice condenser is given by

$$A_O * \left[RNDICE + (1 - RNDICE) * (V/V_O)^{EXPICE} \right],$$

where A_O is the original surface area of the ice (ASURFR on Record HSCCCCC700), V_O is the original volume of the ice, and V is the current volume of the unmelted ice.
(type = real, default = none, units = none)

The values of HTCICE, RNDICE, and EXPICE should be adjusted to obtain the desired ice condenser performance. The value of EXPICE dictates how surface areas changes with melting. A value of 1.0 implies that the area decreases linearly with the volume and is appropriate for transients that lead to rapid axial melting of the ice columns. A value of 0.5 implies a predominantly radial melt typical of slower transients.

2.1.3 MELGEN Input for the Film-Tracking Model

Input data for the film-tracking model are entered on records with identifiers of the form

HSFTijjkk

where

HSFT	indicates that the record is for the film-tracking model with
i	numerical identifier for heat structure networks
jj	sequence number for each heat structure in the network
kk	sequence number for connected drainage heat structures

The following input records are required to describe a network of heat structures connected for the purposes of film tracking. The film-tracking model automatically calculates the total amount of water that drains off of each heat structure surface in the network, and the user provides destination fractions to determine where that drainage goes. The destination fractions allow the user to divide the total drainage among any or all of three types of drainage destinations:

(1) the surface of one or more heat structures in the same network,

(2) the MELCOR Containment Spray (SPR) package (via a user-defined transfer process, see the TP Package Users' Guide) for treatment as "rain" from the surface (this is appropriate for inverted surfaces off which condensation is more likely to drip than drain, e.g. ceilings) and

(3) the pool component of the CVH control volume associated with the given surface.

There may be more than one network in a problem (e.g., one network in the reactor vessel, one network in the steam generators, one network for containment structures, etc.), but no heat structure should be included in more than one network. The heat structures should be listed from the top down on the HSFTijj00 records in the network description; that is, if heat structure A drains to heat structure B, then heat structure A should be listed first (i.e., have a smaller value of jj in its HSFTijj00 record than the value of jj in the HSFTijj00 record that describes heat structure B). Further more, recirculating drainage is not permitted; that is, heat structure B should not drain to heat structure A, if heat structure A is included in the chain of heat structures that drain to heat structure B. All heat structures that receive film drainage from another heat structure or an external source should be included in the network (even though the bottom-most heat structures do not themselves drain to lower structures). Heat structure surfaces which receive film drainage from other heat structures or external sources must support mass transfer; that is, the values of IBCL and IBVL on Record HSCCCCC400 and/or IBCR and IBVR on Record HSCCCCC600 must be positive if drainage is to be tracked on the left and/or right surface(s) of heat structure CCCCC. Finally, the sum of drainage fractions (FRAINs plus all FDRNs for s = L or s = R) for each surface of a heat structure in the network must not exceed one. If the sum of drainage fractions for a surface is less than one, then the excess drainage will go to the pool of the CVH volume associated with that surface.

HSFTi0000 – Network Size Data

$0 \leq i \leq 9$, i is the network identification number
Required

(1) NUMSTR - Number of heat structures in the network
(type = integer, default = none, units = none)

HSFTijj00 – Network Heat Structure Identification and Source Data

i has the same value as i in record HSFTi0000
$01 \leq jj \leq NUMSTR \leq 99$, jj is a sequencing identifier for these records
Required

These records identify and describe the heat structures contained in the network. The first six fields (IDSTRC, NUMDRN, FRAINL, NTPL, FRAINR and NTPR) described below are required. The last four fields should be entered if an external source of water is to be provided for the left and/or right surface(s) of the heat structure.

(1) IDSTRC - Heat structure number (CCCCC value from HSCCCCCxxx records)
(type = integer, default = none, units = none)

(2) NUMDRN - Number of heat structures this structure drains to
(type = integer, default = none, units = none)

(3) FRAINL - Fraction of the total drainage from the left surface of the heat structure that is transferred to the Spray package as "rain."
(type = real, default = none, units = none)

(4) NTPL - The "in" transfer process number for "rain" transfers to the SPR package from the left surface of the structure (enter 0 if FRAINL = 0.; otherwise, enter a positive integer and enter the appropriate TP and SPR input to effect the transfer—see example in Section 5.3.)
(type = integer, default = none, units = none)

(5) FRAINR - Same as FRAINL except for right surface.
(type = real, default = none, units = none)

(6) NTPR - Same as NTPL except for left surface.
(type = integer, default = none, units = none)

(7) IMSRCL - Mass source rate (kg/s) identifier number for left surface; a positive value indicates the source is obtained from tabular function number IMSRCL, a negative value indicates the source is obtained from control function number -IMSRCL and a value of 0 indicates that there is no source.
(type = integer, default = none, units = none)

(8) IESRCL - Specific enthalpy (J/kg) source identifier number for source associated with IMSRCL; a positive value indicates a tabular function, a negative value indicates a control function and 0 indicates there is no source.
(type = integer, default = none, units = none)

(9) IMSRCR - Same as IMSRCL except for right surface of heat structure CCCCC.
(type = integer, default = none, units = none)

(10) IESRCR - Same as IESRCL except it is associated with IMSRCR.
(type = integer, default = none, units = none)

HSFTijjkk – Data for Drainage Heat Structures
i has the same value as i in HSFTi0000
jj has the same value as jj in HSFTijj00
$01 \leq kk \leq NUMDRN \leq 99$, kk is a sequence number for these records
Required if NUMDRN on record HSFTijj00 is positive
Must have NUMDRN of these records

These records identify and describe the heat structures that receive film drainage from heat structure IDSTRC on corresponding HSFTijj00 record.

(1) IDSDRN - The heat structure number (CCCCC value from HSCCCCCxxx records) of the structure receiving the film drainage.
(type = integer, default = none, units = none)

(2) FDRNL - The fraction of the total film drainage from the left surface of heat structure IDSTRC that goes to the left surface of heat structure IDSDRN.
(type = real, default = none, units = none)

(3) FDRNR - Same as FDRNL except applies to right surface of heat structures.
(type = real, default = none, units = none)

2.1.4 MELCOR Input for Structure-to-Structure Radiation

Input data for the structure-to-structure radiation model are input on records of the form HSRDCCCCC0, where CCCCC is a user-defined five digit integer for a given pair of surfaces. Each surface pair must be unique in that the surfaces associated with one pair must not be associated with another. The number of allowable surface pairs is not restricted and is limited only by the amount of computer storage available to the database.

The following record defines the input data required.

HSRDCCCCC0 – Structure-to-Structure Radiation
Optional

(1) IHSRD1 - Heat structure number for the first surface of the pair. A left side surface is identified by the use of a negative structure number while a right side surface is identified by a positive structure number.
(type = integer, default = none, units = none)

(2) IHSRD2 - Heat structure number for the second surface of the pair. The left and right side conventions are the same as above for surface 1.
(type = integer, default = none, units = none)

(3) VIEW - View factor between surface 1 and surface 2.
(type = integer, default = none, units = none)

(4) ICFRD1 - Optional real-valued control function index whose value is the emissivity of surface 1.
(type = integer, default = 0 (see below), uints = none)

(5) ICFRD2 - Optional real-valued control function index whose value is the emissivity of surface 2.
(type = integer, default = 0 (see below), units = none)

The input of 0 or blank for the control function indices specifies the default use of COR Package Reference Manual relation (Equation. 2.10) for determining the emissivity as a function of temperature.

The user should note that use of this model is restricted to the surfaces of structures for which the boundary condition flags (IBCL – input Record HSCCCCC400 and IBCR – Record HSCCCCC600) do not specify either temperature or heat flux. Thus, the options 0, 2XXX, 3XXX, 8XXX, or 9XXX are not permitted for IBCL or IBCR. All other options are permitted.

If the use of control functions is employed, the emissivity is bounded between 0.0 and 1.0, inclusive, prior to its use in determining the radiative exchange. The radiative exchange is zeroed if either of the surface emissivities is zero, if the input view factor is zero, or if either of the surfaces of the pair is covered by a water pool in its adjacent CVH volume.

2.2 MELCOR User Input

This section discusses MELCOR user input for the HS package. All HS package input records are optional for MELCOR execution. Input records are supplied for MELCOR execution only to make permitted changes to the existing data base for the HS package. MELCOR input and these changes are discussed as follows:

Section 2.2.1	Heat Structure input records
Section 2.2.2	Gas Source input records
Section 2.2.3	Film-Tracking input records
Section 2.2.4	MELCOR Input for Structure-to-Structure Radiation

2.2.1 MELCOR Input for Heat Structures

All HS package input records (except for structure-to-structure radiation) are optional for MELCOR execution. Input records for heat structures are supplied for MELCOR execution

only to make changes to time-independent data or temperature distributions on a restart. Any change to the data for a given heat structure is permitted except one which changes the geometry or involves changes in the number of temperature nodes for this heat structure. At present a heat structure may not be added or deleted on a restart. All changes will be propagated through subsequent restarts unless rescinded by their input records.

The following items pertaining to input processing by the HS package during a restart are important and must be conformed to by all MELCOR input for heat structures:

(1) Although a complete set of records does not need to be supplied for each heat structure with data changes during MELCOR execution, each included record must be complete as described in Section 2.1.1. Thus, all fields on a record preceding and following the field which contains the datum to be changed must be present.

One exception to this is modifying the boundary conditions for a heat structure on a restart. If it is desired to change any of the fields on **either** the HSCCCCC400 (401) or HSCCCCC600 (601) boundary surface data records on a restart, then **both** the HSCCCCC400 (401) and HSCCCCC600 (601) records for that heat structure must be included in the MELCOR input.

(2) All fields on each record must conform to the criteria or restrictions as described in Section 2.1.1.

(3) All data location indicators which are described in Section 2.1.1 will be interpreted by the HS package input processor during MELCOR execution as applying to data for Heat Structure MMMMM rather than to data on HSMMMMMXNN records. Therefore, one should provide records containing the new data for Heat Structure CCCCC if the corresponding data will be changed for Heat Structure MMMMM, since the executive input processor sorts records and the desired changes will not be made if CCCCC is less than MMMMM. To be safe, it is recommended that output from MELCOR restarts be examined after a very short test run to ensure that all user changes were correctly processed.

2.2.2 MELCOR Input for Gas Sources

All HS package gas source input records are optional for MELCOR execution. Input records for gas sources are supplied for MELCOR execution only to make changes to time-independent data on a restart. Any change to the data for a given gas source is permitted. At present a gas source may not be added or deleted on a restart. Gas Source CCCCC may be made effectively inactive on a restart by setting its source density (RHOSRC on Record HSDGCCCCC1) to zero. All changes will be propagated through subsequent restarts unless rescinded by their input records.

The following items pertaining to input processing by the HS package during a restart are important and must be conformed to by all MELCOR input for gas sources:

(1) Although a complete set of records does not need to be supplied for each gas source with data changes during MELCOR execution, each included record must be complete as described in Section 2.1.2. Thus, all fields on a record preceding and following the field which contains the datum to be changed must be present.

(2) All fields on each record must conform to the criteria or restrictions as described in Section 2.1.2.

(3) The ISRCHS, ISDIST, and GASNAM input data as identified by input record HSDGCCCCC0 are not permitted to change for "SS" degassing sources.

2.2.3 MELCOR Film-Tracking Model Input

All HS package film-tracking model input records are optional for MELCOR execution. Input records for the film-tracking model are supplied for MELCOR execution only to make changes to time-independent data on a restart. The only data that may be changed are values of FRAINL, NTPL, FRAINR, NTPR, IMSRCL, IESRCL, IMSRCR, IESRCR, FDRNL and FDRNR. Networks and the heat structures included in them may not be added or deleted. Restart changes are primarily provided to alter drainage patterns. The value of NUMSTR specified on record HSFTi0000 for a restart should be equal to the number of heat structures in network i which are to be modified. Similarly, the value of NUMDRN on record HSFTijj00 should be equal to the number of drainage heat structures which are to have their values of FDRNL and/or FDRNR modified.

2.2.4 MELCOR Input Controlling Structure-to-Structure Radiation

Although no MELCOR input is allowed for the structure-to-structure radiation model, the model may be effectively turned on and off for individual radiation pairs by using the control function method of specifying surface emissivities (ICFRD1 and ICFRD2) on MELGEN input records HSRDCCCCC0. For periods during a MELCOR calculation when the calculation of radiation is not desired (between given surfaces previously active in the radiation model), the user can structure the control function such that a zero emissivity (and thus zero radiation heat transfer) is produced. Because control function input is allowed upon MELCOR restarts, this method allows user control of the radiation model during all parts of the MELCOR calculation.

3. Sensitivity Coefficients

The *sensitivity coefficient* feature in MELCOR is a powerful feature that gives the user the ability to change selected parameters the physics models that would otherwise require modification of the Fortran source code. Their use is described in Section 7 of the the MELCOR EXEC Users' Guide.

3.1 HS Sensitivity Coefficients

The sensitivity coefficients for the Heat Structure package have identifier numbers between 4000 and 4299. These are reserved as follows:

4000 – 4049:	Analytic Functions
4050 – 4059:	Iteration Parameters
4060 – 4079	Parameter Ranges for Atmosphere Heat Transfer
4080 – 4099:	Parameter Ranges for Pool Heat Transfer
4100 – 4149:	Atmosphere Heat Transfer Correlations
4150 – 4199:	Pool Heat Transfer Correlations
4200 – 4249:	Mass Transfer Parameters and Correlations
4250 – 4299:	Liquid Film Parameters and Correlations

This section describes the sensitivity coefficients that are presently used in the HS package and gives their default values, units, and EQUIVALENCE names. See the MELCOR/MELGEN Executive Package Users' Guide for details on the use of Sensitivity Coefficient records.

Warning!!

In the present version of the MELCOR Code System, no error testing of the new value of a sensitivity coefficient in the HS package is performed. Therefore, the user is warned that the indiscriminate change of a coefficient may result in nonphysical results or an aborted calculation.

4000 – Surface Tension

The surface tension of water, σ, is given as a function of temperature by:

$$\sigma(T) = C4000(1)x[C4000(2) + C4000(3)xT_R]xT_R^{C4000(4)} + C4000(5)$$

where

$\sigma(T)$ = surface tension, N/m

T = temperature, K

T_R = C4000(6) – T/C4000(7)

C4000(1) - constant coefficient
(default = 0.2358, units = N/m, equiv = none)

C4000(2) - additive constant
(default = 1.0, units = none, equiv = none)

C4000(3) - constant coefficient
(default = -0.625, units = $1/K^{-1}$, equiv = none)

C4000(4) - constant coefficient
(default = 1.256, units = none, equiv = none)

C4000(5) - additive constant
(default = 0.0, units = N/m, equiv = none)

C4000(6) - additive constant
(default = 1.0, units = none, equiv = none)

C4000(7) - critical temperature for water
(default = 647.3, units = K, equiv = none)

4051 – Steady-State Iteration Parameters

These coefficients are iteration parameters which are used for steady-state heat conduction calculations.

C4051(1) - maximum number of permitted steady-state iterations
(default = 400, units = none, equiv = XITMXS)

C4051(2) - desired relative error tolerance for steady-state calculations; iterations will be performed until the relative error in the temperature profile is less than this value or until XITMXS iterations have been performed (see C4051(5) below).
(default = 1.0×10^{-5}, units = none, equiv = ERRSS)

C4051(3) - initial steady-state timestep
(default = 1.0×10^{5}, units = s, equiv = DTSS)

C4051(4) - maximum relative error tolerance for film mass
(default = 1.0×10^{-2}, units = none, equiv = ERFSS)

C4051(5) - maximum relative error tolerance for steady-state calculations; failure will be declared if the relative error in the temperature profile exceeds this value after XITMXS iterations
(default = 1.0×10^{-2}, units = none, equiv = ERDIES)

4052 – Steady-State Iteration Weight Parameters

These coefficients are iteration weight parameters which are used for steady-state heat conduction calculations to mitigate nonconvergence by oscillation. Refer to Section 3.1 of the HS Reference Manual for details on the use of steady-state iteration parameters.

4052(1) - steady-state boiling heat transfer coefficient weight
(default = 0.0, units = none, equiv = WTBSST)

4052(2) - error tolerance for steady-state boiling heat transfer coefficient
(default = 0.05, units = none, equiv = ERBSST)

4055 – Transient Iteration Parameters

These coefficients are iteration parameters which are used for transient conduction calculations.

C4055(1) - maximum number of permitted transient iterations
(default = 30, units = none, equiv = XITMAX)

C4055(2) - desired relative error tolerance for transient conduction calculations; NOTE: the conduction calculation is declared converged when the maximum relative error in the temperature profile within the structure is less than this value, normally. However, if degassing or mass transfer (condensation/ evaporation) is occurring, then the iteration continues until the maximum relative error in the temperature profile (including the film surfaces) is less than the value specified by C4055(6) described below. If the relative error is still larger than C4055(6) but smaller than C4055(2) after XITMAX iterations, then the solution is accepted as converged (see C4055(8) below).
(default = 5.0×10^{-4}, units = none, equiv = ERRTRN)

C4055(3) - minimum number of iterations to limit timestep
(default = 31, units = none, equiv = XITCUT)

C4055(4) - minimum relative error tolerance for material property determination
(default = 0.01, units = none, equiv = RETMIN)

C4055(5) - matrix solver precision limit
(default = 1.0×10^{-10}, units = none, equiv = EPSILL)

C4055(6) - override value for ERRTRN during degassing/mass transfer—see the NOTE for C4055(2) above
(default = 5.0×10^{-6}, units = none, equiv = ERRSML)

C4055(7) - maximum relative error tolerance for film mass
(default = 1.0×10^{-2} units = none, equiv = ERFTRN)

C4055(8) - maximum relative error tolerance for transient calculations; failure will be declared and a request made to repeat the cycle with a smaller timestep if the relative error in the temperature profile exceeds this value after XITMAX iterations
(default = 5.0×10^{-3}, units = none, equiv = ERDIET)

4056 – Transient Iteration Weight Parameters

These coefficients are iteration weight parameters which are used for transient heat conduction calculations to mitigate nonconvergence by oscillation. Refer to Section 3.1 of the HS Reference Manual for details on the use of transient iteration parameters.

C4056(1) - transient boiling heat transfer coefficient weight
(default = 0.9, units = none, equiv = WTBTRN)

C4056(2) - error tolerance for transient boiling heat transfer coefficient
(default = 0.05, units = none, equiv = ERBTRN)

4060 – Atmosphere Natural and Forced Convection Ranges

These coefficients define the limits of natural and forced convection heat transfer to the atmosphere. In general, a mixed convection regime is also considered, and the convection heat transfer to the atmosphere is determined by the following criteria:

Natural Convection if $Re^2 <$ C4060(1)xGr
Forced Convection if $Re^2 >$ C4060(2)xGr
Mixed Convection if C4060(1)x$Gr \leq Re^2 \leq$ C4060(2)xGr

where

Re = Reynolds number for atmosphere

Gr = Grashof number for atmosphere

However, if C4060(1) < 0 or C4060(2) ≤ C4060(1), convection heat transfer to the atmosphere is assumed to be given by the greater of the values defined by the natural and forced convection correlations.

C4060(1) - constant coefficient
(default = 1.0, units = none, equiv = none)

C4060(2) - constant coefficient
(default = 10.0, units = none, equiv = none)

4061-4063 – Atmosphere Laminar and Turbulent Natural Convection Ranges

These coefficients define the limits of laminar and turbulent natural convection heat transfer to the atmosphere. In general, a transition regime is also considered, and the natural convection heat transfer to the atmosphere is determined by the following criteria:

Laminar if Ra < C406m(1)
Turbulent if Ra > C406m(2)
Transition if C406m(1) ≤ Ra ≤ C406m(2)

where

Ra = Rayleigh number for atmosphere

m = 1 for rectangular geometries

= 2 for cylindrical geometries

= 3 for spherical or hemispherical geometries

However, if C406m(1) < 0 or C406m(2) ≤ C406m(1), natural convection heat transfer to the atmosphere is assumed to be given by the greater of the values defined by the laminar and turbulent natural convection correlations.

<u>Rectangular</u>
C4061(1) - Rayleigh number upper limit for atmosphere laminar natural convection
(default = 10^9, units = none, equiv = none)

C4061(2) - Rayleigh number lower limit for atmosphere turbulent natural convection
(default = 10^{10}, units = none, equiv = none)

Cylindrical

C4062(1) - Rayleigh number upper limit for atmosphere laminar natural convection
(default = 10^{9}, units = none, equiv = none)

C4062(2) - Rayleigh number lower limit for atmosphere turbulent natural convection
(default = 10^{10}, units = none, equiv = none)

(Hemi)spherical

C4063(1) - Rayleigh number upper limit for atmosphere laminar natural convection
(default = 10^{9}, units = none, equiv = none)

C4063(2) - Rayleigh number lower limit for atmosphere turbulent natural convection
(default = 10^{10}, units = none, equiv = none)

4064-4066 – Atmosphere Laminar and Turbulent Forced Convection Ranges

These coefficients define the limits of laminar and turbulent forced convection heat transfer to the atmosphere. In general, a transition regime is also considered, and the forced convection heat transfer to the atmosphere is determined by the following criteria:

Laminar if Re < C406m(1)
Turbulent if Re > C406m(2)
Transition if C406m(1) $\leq$ Re $\leq$ C406m(2)

where

m = 4 for rectangular geometries

= 5 for cylindrical geometries

= 6 for spherical or hemispherical geometries

However, if C406m(1) < 0 or C406m(2) ≤ C406m(1), forced convection heat transfer to the atmosphere is assumed to be given by the greater of the values defined by the laminar and turbulent forced convection correlations.

Rectangular

C4064(1) - Reynolds number upper limit for atmosphere laminar forced convection
(default = $3x10^5$, units = none, equiv = none)

C4064(2) - Reynolds number lower limit for atmosphere turbulent forced convection
(default = $6x10^5$, units = none, equiv = none)

Cylindrical

C4065(1) - Reynolds number upper limit for atmosphere laminar forced convection
(default = 2000, units = none, equiv = none)

C4065(2) - Reynolds number lower limit for atmosphere turbulent forced convection
(default = 10^4, units = none, equiv = none)

(Hemi)spherical

C4066(1) - Reynolds number upper limit for atmosphere laminar forced convection
(default = 2000, units = none, equiv = none)

C4066(2) - Reynolds number lower limit for atmosphere turbulent forced convection
(default = 10^4, units = none, equiv = none)

4071 – Bounds on Critical Pool Fractions

As described in Section 2.4 of the Heat Structures Package Reference Manual, heat transfer from a heat structure surface to the pool and/or atmosphere of an adjacent control volume is controlled by user input critical pool fractions on the HSCCCCC400 and HSCCCCC600 input records. These sensitivity coefficients impose bounds on the user-input values, to prevent transfer of heat to insignificant fluid masses.

C4071(1) - Lower bound imposed on input values of CPFPL and CFFPR
(default = 0.02, units = none, equiv = none)

C4071(2) - Upper bound imposed on input values of CPFAL and CFPAR

(default = 0.98, units = none, equiv = none)

4080 – Pool Natural and Forced Convection Ranges

These coefficients define the limits of natural and forced convection heat transfer to the pool. In general, a mixed convection regime is also considered, and the convection heat transfer to the pool is determined by the following criteria:

Natural Convection if $Re^2 < C4080(1) \times Gr$
Forced Convection if $Re^2 > C4080(2) \times Gr$
Mixed Convection if $C4080(1) \times Gr \leq Re^2 \leq C4080(2) \times Gr$

where

Re = Reynolds number for pool

Gr = Grashof number for pool

However, if $C4080(1) < 0$ or $C4080(2) \leq C4080(1)$, convection heat transfer to the pool is assumed to be given by the greater of the values defined by the natural and forced convection correlations.

C4080(1) - constant coefficient
(default = 1.0, units = none, equiv = none)

C4080(2) - constant coefficient
(default = 10.0, units = none, equiv = none)

4081 – **4083** – Pool Laminar and Turbulent Natural Convection Ranges

These coefficients define the limits of laminar and turbulent natural convection heat transfer to the pool. In general, a transition regime is also considered, and the natural convection heat transfer to the pool is determined by the following criteria:

Laminar if $Ra < C408m(1)$
Turbulent if $Ra > C408m(2)$
Transition if $C408m(1) \leq Ra \leq C408m(2)$

where

Ra = Rayleigh number for pool

m = 1 for rectangular geometries

= 2 for cylindrical geometries

= 3 for spherical or hemispherical geometries

However, if C408m(1) < 0 or C408m(2) ≤ C408m(1), natural convection heat transfer to the pool is assumed to be given by the greater of the values defined by the laminar and turbulent natural convection correlations.

Rectangular

C4081(1) - Rayleigh number upper limit for pool laminar natural convection (default = 10^9, units = none, equiv = none)

C4081(2) - Rayleigh number lower limit for pool turbulent natural convection (default = 10^{10}, units = none, equiv = none)

Cylindrical

C4082(1) - Rayleigh number upper limit for pool laminar natural convection (default = 10^9, units = none, equiv = none)

C4082(2) - Rayleigh number lower limit for pool turbulent natural convection (default = 10^{10}, units = none, equiv = none)

(Hemi)spherical

C4083(1) - Rayleigh number upper limit for pool laminar natural convection (default = 10^9, units = none, equiv = none)

C4083(2) - Rayleigh number lower limit for pool turbulent natural convection (default = 10^{10}, units = none, equiv = none)

4084-4086 – Pool Laminar and Turbulent Forced Convection Ranges

These coefficients define the limits of laminar and turbulent forced convection heat transfer to the pool. In general, a transition regime is also considered, and the forced convection heat transfer to the pool is determined by the following criteria:

Laminar if Re < C408m(1)
Turbulent if Re > C408m(2)
Transition if C408m(1) ≤ Re ≤ C408m(2)

where

m = 4 for rectangular geometries

= 5 for cylindrical geometries

= 6 for spherical or hemispherical geometries

However, if C408m(1) < 0 or C408m(2) ≤ C408m(1), forced convection heat transfer to the pool is assumed to be given by the greater of the values defined by the laminar and turbulent forced convection correlations.

Rectangular

C4084(1) - Reynolds number upper limit for pool laminar forced convection (default = 3 x 10^5, units = none, equiv = none)

C4084(2) - Reynolds number lower limit for pool turbulent forced convection (default = 6 x10^5, units = none, equiv = none)

Cylindrical

C4085(1) - Reynolds number upper limit for pool laminar forced convection (default = 2000, units = none, equiv = none)

C4085(2) - Reynolds number lower limit for pool turbulent forced convection (default = 10^4, units = none, equiv = none)

(Hemi)spherical

C4086(1) - Reynolds number upper limit for pool laminar forced convection (default = 2000, units = none, equiv = none)

C4086(2) - Reynolds number lower limit for pool turbulent forced convection (default = 10^4,units = none, equiv = none)

4101-4112 – Atmosphere Natural Convection

The atmosphere natural convection heat transfer correlations have the following form:

$$Nu = C41mm(1)\ x\ Ra^{C41mm(2)} + C41mm(3)$$

where

Nu = Nusselt number

Ra = Rayleigh number

mm = 01 (04) for laminar (turbulent) correlations for rectangular geometries in internal flow

= 02 (05) for laminar (turbulent) correlations for cylindrical geometries in internal flow

= 03 (06) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow

= 07 (10) for laminar (turbulent) correlations for rectangular geometries in external flow

= 08 (11) for laminar (turbulent) correlations for cylindrical geometries in external flow

= 09 (12) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the atmosphere natural convection heat transfer correlations are summarized in Table 3.1. All are dimensionless and have no assigned EQUIVALENCE names.

Table 3.1 Default Values for Sensitivity Coefficients 4101 – 4124

Atmosphere Related					
Array	Type of Flow	1	2	3	4
C4101	L,I,R,NC	0.046	1/3	0	-
C4102	L,I,C,NC	0.046	1/3	0	-
C4103	L,I,S,NC	0.228	0.226	0	-
C4104	T,I,R,NC	0.046	1/3	0	-
C4105	T,I,C,NC	0.046	1/3	0	-
C4106	T,I,S,NC	0.228	0.226	0	-
C4107	L,E,R,NC	0.59	0.25	0	-
C4108	L,E,C,NC	0.59	0.25	0	-
C4109	L,E,S,NC	0.43	0.25	2.0	-
C4110	T,E,R,NC	0.10	1/3	0	-
C4111	T,E,C,NC	0.10	1/3	0	-
C4112	T,E,S,NC	0.43	0.25	2.0	-
C4113	L,I,R,FC	8.235	0	0	0
C4114	L,I,C,FC	48/11	0	0	0
C4115	L,I,S,FC	48/11	0	0	0
C4116	T,I,R,FC	0.023	0.8	1/3	0
C4117	T,I,C,FC	0.023	0.8	1/3	0
C4118	T,I,S,FC	0.023	0.8	1/3	0

Atmosphere Related					
Array	Type of Flow	1	2	3	4
C4119	L,E,R,FC	0.664	0.5	1/3	0
C4120	L,E,C,FC	0.664	0.5	1/3	0
C4121	L,E,S,FC	0.60	0.5	1/3	2.0
C4122	T,E,R,FC	0.037	0.8	1/3	0
C4123	T,E,C,FC	0.037	0.8	1/3	0
C4124	T,E,S,FC	0.60	0.5	1/3	2.0

L=Laminar, T=Turbulent, I=Internal, E=External, R=Rectangular, C=Cylindrical, S=(Hemi)spherical, NC=Natural Convection, FC=Forced Convection

4113-4124 – Atmosphere Forced Convection

The atmosphere forced convection heat transfer correlations have the following form:

$$Nu = C41mm(1)x\,\mathrm{Re}^{C41mm(2)}\,x\,\mathrm{Pr}^{C41mm(3)} + C41mm(4)$$

where

Nu = Nusselt number

Re = Reynolds number

Pr = Prandtl number

mm = 13 (16) for laminar (turbulent) correlations for rectangular geometries in internal flow

= 14 (17) for laminar (turbulent) correlations for cylindrical geometries in internal flow

= 15 (18) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow

= 19 (22) for laminar (turbulent) correlations for rectangular geometries in external flow

= 20 (23) for laminar (turbulent) correlations for cylindrical geometries in external flow

= 21 (24) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the atmosphere forced convection heat transfer correlations are summarized in Table 3.1. All are dimensionless and have no assigned EQUIVALENCE names.

4151-4162 – Pool Natural Convection

The pool natural convection heat transfer correlations have the following form:

$$Nu = C41mm(1)xRa^{C41mm(2)} + C41mm(3)$$

where

Nu = Nusselt number

Ra = Rayleigh number

mm = 51 (54) for laminar (turbulent) correlations for rectangular geometries in internal flow

= 52 (55) for laminar (turbulent) correlations for cylindrical geometries in internal flow

= 53 (56) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow

= 57 (60) for laminar (turbulent) correlations for rectangular geometries in external flow

= 58 (61) for laminar (turbulent) correlations for cylindrical geometries in external flow

= 59 (62) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the pool natural convection heat transfer correlations are summarized in Table 3.2. All are dimensionless and have no assigned EQUIVALENCE names.

Table 3.2 Default Values for Sensitivity Coefficients 4151 – 4174

Pool Related					
Array	Type of Flow	1	2	3	4

Pool Related					
Array	Type of Flow	1	2	3	4
C4151	L,I,R,NC	0.046	1/3	0	-
C4152	L,I,C,NC	0.046	1/3	0	-
C4153	L,I,S,NC	0.228	0.226	0	-
C4154	T,I,R,NC	0.046	1/3	0	-
C4155	T,I,C,NC	0.046	1/3	0	-
C4156	T,I,S,NC	0.228	0.226	0	-
C4157	L,E,R,NC	0.59	0.25	0	-
C4158	L,E,C,NC	0.59	0.25	0	-
C4159	L,E,S,NC	0.43	0.25	2.0	-
C4160	T,E,R,NC	0.10	1/3	0	-
C4161	T,E,C,NC	0.10	1/3	0	-
C4162	T,E,S,NC	0.43	0.25	2.0	-
C4163	L,I,R,FC	8.235	0	0	0
C4164	L,I,C,FC	48/11	0	0	0
C4165	L,I,S,FC	48/11	0	0	0
C4166	T,I,R,FC	0.023	0.8	1/3	0
C4167	T,I,C,FC	0.023	0.8	1/3	0
C4168	T,I,S,FC	0.023	0.8	1/3	0
C4169	L,E,R,FC	0.664	0.5	1/3	0
C4170	L,E,C,FC	0.664	0.5	1/3	0
C4171	L,E,S,FC	0.60	0.5	1/3	2.0
C4172	T,E,R,FC	0.037	0.8	1/3	0
C4173	T,E,C,FC	0.037	0.8	1/3	0
C4174	T,E,S,FC	0.60	0.5	1/3	2.0

L=Laminar, T=Turbulent, I=Internal, E=External, R=Rectangular,
C=Cylindrical, S=(Hemi)spherical, NC=Natural Convection, FC=Forced Convection

4163-4174 – Pool Forced Convection

The pool forced convection heat transfer correlations have the following form:

$$Nu = C41mm(1)x\,\mathrm{Re}^{C41mm(2)}\,x\,\mathrm{Pr}^{C41mm(3)} + C41mm(4)$$

where

Nu = Nusselt number

Re = Reynolds number

Pr = Prandtl number

mm = 63 (66) for laminar (turbulent) correlations for rectangular geometries in internal flow

= 64 (67) for laminar (turbulent) correlations for cylindrical geometries in internal flow

= 65 (68) for laminar (turbulent) correlations for spherical or hemispherical geometries in internal flow

= 69 (72) for laminar (turbulent) correlations for rectangular geometries in external flow

= 70 (73) for laminar (turbulent) correlations for cylindrical geometries in external flow

= 71 (74) for laminar (turbulent) correlations for spherical or hemispherical geometries in external flow

The default values of the coefficients for the pool forced convection heat transfer correlations are summarized in Table 3.2. All are dimensionless and have no assigned EQUIVALENCE names.

4180 – Nucleate Boiling Heat Flux

The nucleate boiling heat flux is obtained through the Rohsenow relation,

$$\left[\frac{C_{pl}\left(T_{surf}-T_{sat}\right)}{h_{fg}}\right]=C4180(1)x\,\mathrm{Pr}^{C4180(3)}\,x\left[\frac{q''_{NB}}{\mu h_{fg}}\left\{\frac{\sigma}{g\left(\rho_l-\rho_v\right)}\right\}^{1/2}\right]^{C4180(4)}$$

where

q''_{NB} = nucleate boiling heat flux, W/m^2

c_{pl} = heat capacity of liquid at T_{sat}, J/kg • K

T_{surf} = temperature of surface, K

T_{sat} = saturation temperature in boundary volume, K

h_{fg} = latent heat in boundary volume of this surface, J/kg

Pr = Prandtl number of liquid in boundary volume

μ = dynamic viscosity of liquid at $T_{avg,}$ kg/m • s

T_{avg} = $(T_{surf} + T_{sat})/2$, K

σ = surface tension at $T_{avg,}$ N/m

g = acceleration of gravity, m/s^2

ρ_l = density of liquid at $T_{sat,}$ kg/m^3

ρ_v = density of vapor at $T_{sat,}$ kg/m^3

C4180(1) - constant determined empirically for different surfaces and fluids (default = 0.013, units = none, equiv = none)

C4180(2) - unused

C4180(3) - Prandtl number exponent (default = 1.0, units = none, equiv = none)

C4180(4) - exponent (default = 0.33, units = none, equiv = none)

4181 – Critical Heat Flux

The critical heat flux is given by Zuber as

$$q''_c = C4181(1) x \rho_v h_{fg} \left[\sigma(\rho_l - \rho_v) g / \rho_v^2\right]^{C4181(2)} x \left[\rho_l / (\rho_l + \rho_v)\right]^{C4181(3)}$$

where

q''_c = critical heat flux, W/m^2

ρ_v = density of vapor at $T_{sat,}$ kg/m^3

ρ_l = density of liquid at $T_{sat,}$ kg/m^3

h_{fg} = latent heat in boundary volume, J/kg

g = acceleration of gravity, m/s^2

σ = surface tension at $T_{avg,}$ N/m

T_{avg} = (T_{surf} + T_{sat}) / 2, K

T_{sat} = saturation temperature in boundary volume, K

T_{surf} = temperature of this surface, K

C4181(1) - constant coefficient
(default = 0.18, units = none, equiv = none)

C4181(2) - exponent
(default = 0.25, units = none, equiv = none)

C4181(3) - exponent
(default = 0.5, units = none, equiv = none)

4182 – Minimum Film Boiling Heat Flux

The minimum film boiling heat flux is given by Zuber as

$$q''_{mfilm} = C4182(1)\rho_v h_{fg}\left[\sigma(\rho_l - \rho_v)g / \rho_l^2\right]^{C4182(2)} x\left[\rho_l(\rho_l + \rho_v)\right]^{C4182(3)}$$

where

q''_{mfilm} = minimum film boiling heat flux, W/m^2

C4182(1) - constant coefficient
(default = 0.09, units = none, equiv = none)

C4182(2) - exponent
(default = 0.25, units = none, equiv = none)

C4182(3) - exponent
(default = 0.5, units = none, equiv = none)

4183 – Film Boiling Heat Flux

The film boiling heat flux is given by Bromley as

$$q''_{film} = C4183(1)x\left[\rho_v(\rho_l - \rho_v)g\,k_v^3\left(h_{fg} + \frac{1}{2}c_{pv}\Delta T\right)/\mu_v L_c\right]^{C4183(2)} x\Delta T^{C4183(3)}$$

where

q''_{film} = film boiling heat flux, W/m^2

L_c = characteristic length of this surface, m

ΔT = $T_{surf} - T_{sat}$, K

T_{surf} = temperature of this surface, K

T_{sat} = saturation temperature in boundary volume, K

g = acceleration due to gravity, m/s^2

h_{fg} = latent heat in boundary volume, J/kg

ρ_l = density of liquid at T_{sat}, kg/m^3

ρ_v = density of vapor at T_{sat}, kg/m^3

c_{pv} = heat capacity of vapor at T_{sat}, J/kg • K

T_{avg} = (T_{surf} + T_{sat}) / 2, K

μ_v = dynamic viscosity of vapor at T_{avg}, kg/m • s

k_v = thermal conductivity of vapor at T_{avg}, W/m • K

C4183(1) - constant coefficient
(default = 0.943, units = none, equiv = none)

C4183(2) - exponent
(default = 0.25, units = none, equiv = none)

C4183(3) - exponent
(default = 0.75, units = none, equiv = none)

4184 – Radiation to Pool Heat Flux (Plane Model)

The radiation to pool heat flux is given by

$$q''_{rad} = C4184(1) x \sigma \left(T^4_{surf} - T^4_{pool} \right)$$

where

q''_{rad} = radiation to pool heat flux, W/m^2

T_{surf} = temperature of surface, K

T_{pool} = temperature of pool in boundary volume, K

σ = Stefan-Boltzmann constant, 5.669x10^{-8} W/m^2 • K^4

C4184(1) - constant coefficient
(default = 1.0, units = none, equiv = none)

4200 – Mass Transfer Flux Model Transition Parameter

The condensation/evaporation mass flux is not limited by the presence of noncondensible gases if the ratio of the steam partial pressure to the total pressure in the bulk atmosphere exceeds this parameter.

C4200(1) - ratio of steam partial pressure to total pressure in bulk atmosphere
(default = 0.9995, units = none, equiv = VPFRAC)

4201 – Sherwood Number for Diffusion Mass Transfer

A Sherwood Number Correlation is used to calculate a diffusion mass transfer coefficient. The correlation has the following form:

$$Sh = C4201(1) x Nu^{C4201(2)} x Sc^{C4201(3)} x \mathrm{Pr}^{C4201(4)}$$

where

Nu = Nusselt number

Sc = Schmidt number

Pr = Prandtl number

C4201(1) - constant coefficient
(default = 1.0, units = none, equiv = none)

C4201(2) - Nusselt number exponent
(default = 1.0, units = none, equiv = none)

C4201(3) - Schmidt number exponent
(default = 1/3, unit = none, equiv = none)

C4201(4) - Prandtl number exponent
(default = 1/3, units = none, equiv = none)

4202 – Film Flashing Heat Transfer Coefficient

This parameter is used to limit the rate of film evaporation calculated by the mechanistic formula used when noncondensibles are present. The mechanistic formula is

$$\dot{m}_c = h_D \rho_v \ln\left(\Delta P_{srf} / \Delta P_{atm}\right)$$

where

$\dot{m}_c$ = mass flux at this surface, kg/m^2 • s

h_D = mass transfer coefficient, m/s

ρ_v = density of vapor at $T_{sat}(P_{tot})$, kg/m^3

ΔP_{srf} = P_{tot} - P_{srf} = noncondensible partial pressure at the surface temperature, Pa

ΔP_{atm} = P_{tot} - P_{stm} = noncondensible partial pressure in the bulk atmosphere, Pa

P_{tot} = total control volume pressure, Pa

P_{srf} = saturation pressure of steam at the surface temperature, Pa

P_{stm} = steam partial pressure in the control volume, Pa

Because this equation is singular when the P_{srf} reaches P_{tot} it is necessary to bound the rate of evaporation as the surface temperature reaches T_{sat} (P_{tot}). This is done by using a flashing heat transfer coefficient to limit the rate of evaporation as follows:

$$\dot{m}_e = h_e \min\left(0, T_{dew} - T_{srf}\right) / h_{fg}$$

$$\dot{m} = \max\left(\dot{m}_c, \dot{m}_e\right)$$

where

h_e = maximum flashing heat transfer coefficient, W/m^2 • K

h_{fg} = latent heat of vaporization for steam, J/kg

T_{dew} = control volume dew point temperature, K

T_{srf} = surface temperature, K

and h_e has been implemented as sensitivity coefficient 4202, with a default value of 5. x 10^5 W/m^2 – K as follows.

C4202(1) - maximum evaporative heat transfer coefficient (default = 5.x10^5, units = W/m^2 • K, equiv = HTFLSH)

4203 – CVH Steam Depletion Control Parameters

These parameters determine what corrective measure is applied if the calculated condensation rates cause excessive steam depletion in a CVH control volume. Steam depletion is considered excessive if the mass of steam condensed during any timestep exceeds C4203(2) x $M_{stm,0}$, where $M_{stm,0}$ is the initial mass of steam in the control volume at the beginning of the timestep. When excessive condensation occurs, one of two corrective actions is taken. By default, the recommended procedure is to repeat the cycle with a smaller timestep to avoid the problem. The alternative, which is invoked any time the current timestep is less than the value of C4203(1), is to scale the calculated condensation fluxes in the offending control volume by a calculated factor less than one, which will eliminate the excessive condensation. The scaling method is not recommended, except as a last resort, because it can artificially limit the true rate of condensation. As an alternative to scaling the condensation rate or limiting the timestep, it may be preferable to renodalize the problem to reduce the ratio of the HS structure surface area to the CVH volume in the region of the excessive condensation.

C4203(1) - fallback/scaling time-step size transition parameter (default = -1.0, units = s, equiv = none)

C4203(2) - maximum steam mass fraction which may condense per timestep (default = 0.9, units = none, equiv = none)

4205 – Stainless Steel Melting (degassing) Parameters

These parameters control the melting of stainless steel heat structures via the degassing model.

C4205(1) - mass of unmelted steel below which the heat structure is deactivated and the remaining mass relocated to the COR package
(default = 10., units = kg, equiv = none)

4210-4232 – Film Heat Transfer Coefficient Correlations

Laminar or turbulent heat transfer through the condensate film is determined by the following criteria:

Laminar if Re_f < C42m0(1)
Turbulent if Re_f > C42m0(2)
Transition if C42m0(1) $\leq$ Re_f $\leq$ C42m0(2)

where

Re_f = Reynolds number for the film flow

The laminar heat transfer coefficient through the film, $h_{f,l}$, is given by

$$h_{f,l} = \left(k_f / L\right) \; x \;\; Nu_{f,l}$$

where the laminar film Nusselt number, $Nu_{f,l,}$ is given by

$$Nu_{f,l} = C42m1(1) x \left\{ g \; \rho_f \left(\rho_f - \rho_v\right) h_{fg} L^3 \sin\theta / \left[\mu_f k_f \left(T_{sat} - T_{srf}\right)\right] \right\}^{C42m1(2)}$$

The turbulent heat transfer coefficient through the film, $h_{f,t}$, is given by

$$h_{f,t} = \left\{ k_f / \left[\left(\mu_f / \rho_f\right)^2 / g \right]^{C42m2(1)} \right\} x \;\; Nu_{f,t}$$

where the turbulent film Nusselt number, $Nu_{f,t}$ is given by

$$Nu_{f,t} = \left(\mathrm{Re}_f^{C42m2(2)} + C42m2(3)\mathrm{Re}_f^{C42m2(4)}\,\mathrm{Pr}_f^{C42m2(5)}\right)^{C42m2(6)}$$

The transition heat transfer coefficient through the film, $h_{f,\mathrm{tr}}$, is given by linear interpolation of Re_f as

$$h_{f,tr} = h'_{f,l} + \left[h'_{f,t} - h'_{f,l}\right] x \left[\mathrm{Re}_f - C42m0(1)\right] / \left[C42m0(2) - C42m0(1)\right]$$

In each of these equations,

k_f = thermal conductivity of film

L = characteristic length of surface

ρ_f = density of film

ρ_v = density of vapor

g = acceleration of gravity

h_{fg} = latent heat of vaporization corrected for sensible heat

$$\left(h_{fg} + 0.68\, c_{p,f}\left(T_f - T_{srf}\right)\right)$$

$c_{p,f}$ = specific heat capacity of film

T_f = temperature of film/atmosphere interface

T_{srf} = temperature of film/structure interface

μ_{f} = viscosity of film

θ = angle between horizontal and structure surface or axis (cyl.)

$h'_{f,l}$ = $h_{f,l}$ evaluated with Re_f = C42m0(1)

$h'_{f,t}$ = $h_{f,t}$ evaluated with Re_f = C42m0(2)

and

m = 1 for upward-facing rectangular geometries

= 2 for horizontal cylindrical geometries

= 3 for spherical or hemispherical geometries

For downward-facing rectangular geometries, the laminar/turbulent transition criteria are given by:

Laminar if Ra_f < C4213(2)
Turbulent, otherwise

where

Ra_f = Rayleigh number for the film flow

The heat transfer coefficient through the film is given by

$$h_f = \{k_f / [\sigma_f / g(\rho_f - \rho_v)\cos\theta]\}^{1/2} x Nu_f$$

where the film Nusselt number is given by

$$Nu_f = C4214(1) x \{\max[C4213(1), Ra_f]\}^{C4214(2)}$$

for laminar film flow, and

$$Nu_f = C4215(1) x \{\min[C4213(3), Ra_f]\}^{C4215(2)}$$

for turbulent film flow.

Rectangular (upward facing)

C4210(1) - Reynolds number upper limit for laminar film flow (default = 30.0, units = none, equiv = none)

C4210(2) - Reynolds number lower limit for turbulent film flow (default = 100.0, units = none, equiv = none)

C4210(3) - (do not use)

C4210(4) - Sine of minimum angle from horizontal (default = 0.1686289, units = none, equiv = none)

C4211(1) - Laminar correlation leading coefficient

(default = 0.943, units = none, equiv = none)

C4211(2) - Laminar correlation exponent
(default = 0.25, units = none, equiv = none)

C4212(1) - Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4212(2) - Turbulent correlation exponent
(default = - 0.44, units = none, equiv = none)

C4212(3) - Turbulent correlation coefficient
(default = 5.82×10^{-6}, units = none, equiv = none)

C4212(4) - Turbulent correlation exponent
(default = 0.8, units = none, equiv = none)

C4212(5) - Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4212(6) - Turbulent correlation exponent
(default = 0.5, units = none, equiv = none)

Rectangular (downward facing)

C4213(1) - Lower constraint on Ra_f
(default = 10^6, units = none, equiv = none)

C4213(2) - Transition value of Ra_f
(default = 10^8, units = none, equiv = none)

C4213(3) - Upper constraint on Ra_f
(default = 10^{10}, units = none, equiv = none)

C4214(1) - Laminar correlation leading coefficient
(default = 0.6, units = none, equiv = none)

C4214(2) - Laminar correlation exponent
(default = 0.2, units = none, equiv =none)

C4215(1) - Turbulent correlation leading coefficient
(default = 0.72, units = none, equiv = none)

C4215(2) - Turbulent correlation exponent
(default = 0.19, units = none, equiv = none)

NOTE: To avoid potential numerical difficulties the laminar and turbulent correlations must be continuous at the transition Ra_f number given by C4213(2).

Horizontal Cylindrical

C4220(1) - Reynolds number upper limit for laminar film flow (default = 30.0,units = none, equiv = none)

C4220(2) - Reynolds number lower limit for turbulent film flow (default = 100.0, units = none, equiv = none)

C4220(3) - (do not use)

C4220(4) - Cosine of maximum angle from horizontal (default = 0.9715642, units = none, equiv = none)

NOTE: If the value of C4220(4) is set equal to 0., then the cylindrical correlations will be applied to all cylinders. As long as the radius of the cylinder is very large compared to the film thickness, use of the correlations, irrespective of the angle of inclination, is probably justified. Since many important structures are vertical cylinders (e.g., containment vessels, reactor vessels, core shrouds and baffles), the matter should be given careful consideration.

C4221(1) - Laminar correlation leading coefficient (default = 0.729, units = none, equiv = none)

C4221(2) - Laminar correlation exponent (default = 0.25, units = none, equiv = none)

C4222(1) - Turbulent correlation exponent (default = 0.3333333, units = none, equiv = none)

C4222(2) - Turbulent correlation exponent (default = - 0.44, units = none, equiv = none)

C4222(3) - Turbulent correlation coefficient (default = 5.82×10^{-6}, units = none, equiv = none)

C4222(4) - Turbulent correlation exponent (default = 0.8, units = none, equiv = none)

C4222(5) - Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4222(6) - Turbulent correlation exponent
(default = 0.5, units = none, equiv = none)

(Hemi)spherical

C4230(1) - Reynolds number upper limit for laminar film flow
(default = 30.0, units = none, equiv = none)

C4230(2) - Reynolds number lower limit for turbulent film flow
(default = 100.0, units = none, equiv = none)

C4231(1) - Laminar correlation leading coefficient
(default = 0.815, units = none, equiv = none)

C4231(2) - Laminar correlation exponent
(default = 0.25, units = none, equiv = none)

C4232(1) - Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4232(2) - Turbulent correlation exponent
(default = - 0.44, units = none, equiv = none)

C4232(3) - Turbulent correlation coefficient
(default = 5.82×10^{-6}, units = none, equiv = none)

C4232(4) - Turbulent correlation exponent
(default = 0.8, units = none, equiv = none)

C4232(5) - Turbulent correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4232(6) - Turbulent correlation exponent
(default = 0.5, units = none, equiv = none)

4251 – Minimum and Maximum Liquid Film Thickness

These coefficient represent the minimum and maximum thickness of a liquid film on a surface. The maximum film thickness will be ignored if film tracking is active.

C4251(1) - constant minimum film thickness
(default = 10^{-9}, units = m, equiv = FILMIN)

C4251(2) - constant maximum film thickness
(default = 0.0005, units = m, equiv = FILMAX)

4253 – Film-Tracking Model Correlation Parameters

The film thickness, δ_f, is given as a function of the Reynolds number of the film flow by the following correlation

$$\delta_f = C4253(1)\cdot\delta^*\cdot \mathrm{Re}_f^{\,C4253(2)},\ \text{if } \mathrm{Re}_f < C4253(5)$$

$$= C4253(3)\cdot\delta^*\cdot \mathrm{Re}_f^{C4253(4)},\ \text{if } \mathrm{Re}_f < C4253(6)$$

= value determined by linear interpolation between boundary limits

and, during film tracking, the heat transfer coefficient through the film is given by

$$h_f = k_f/\delta_f,\ \text{if}\ \mathrm{Re}_f < C4253(5)$$
$$= (k_f/\delta^*)\left[\mathrm{Re}_f^{C4253(7)} + C4253(8)\mathrm{Re}_f^{C4253(9)}\mathrm{Pr}_f^{C4253(10)}\right]^{C4253(11)},\ \text{if}\ \mathrm{Re}_f > C4253(6)$$

= value determined by linear interpolation between boundary limits

where

$$\delta^* = \left[(\mu_f \rho_f\ )^2/(g\cdot\sin\theta)\right]^{1/3}$$

And k_f, μ_f, ρ_f, and Pr_f are the thermal conductivity, viscosity, density and Prandtl number of the film, respectively, and θ is the angle of the surface with respect to horizontal.

C4253(1) - low Reynolds number film thickness correlation constant
(default = 0.909, units = none, equiv = none)

C4253(2) - low Reynolds number film thickness correlation exponent
(default = 0.3333333, units = none, equiv = none)

C4253(3) - high Reynolds number film thickness correlation constant
(default = 0.115, units = none, equiv = none)

C4253(4) - high Reynolds number film thickness correlation exponent

(default = 0.6, units = none, equiv = none)

C4253(5) - low Reynolds number limit
(default = 1000., units = none, equiv = none)

C4253(6) - high Reynolds number limit
(default = 3000., units = none, equiv = none)

C4253(7) - high Reynolds number film heat transfer coefficient exponent
(default = -0.44, units = none, equiv = none)

C4253(8) - high Reynolds number film heat transfer coefficient constant
(default = $5.82 \cdot 10^{-6}$, units = none, equiv = none)

C4253(9) - high Reynolds number film heat transfer coefficient exponent
(default = 0.8, units = none, equiv = none)

C4253(10) - high Reynolds number film heat transfer coefficient exponent
(default = 0.3333333, units = none, equiv = none)

C4253(11) - high Reynolds number film heat transfer coefficient exponent
(defaut = 0.5, units = none, equiv = none)

4. Plot Variables and Control Function Arguments

Section 4 lists and describes the plot variables and control function arguments which are currently available for the Heat Structure package. Within slashes (/ /) a 'p' denotes a plot variable and a 'c' denotes a control function argument.

HS-CPUC	/p/	Total CPU time used for HS package calculations (s)
HS-CPUE	/p/	Total CPU time used for HS package edits (s)
HS-CPUR	/p/	Total CPU time used for HS package restarts (s)
HS-DEGAS-ENERGY.GGGG	/cp/	Total energy of released gas from Gas Source GGGGG (J)
HS-DEGAS-MASS.GGGGG	/cp/	Total mass of released gas from Gas Source GGGGG (kg)

HS-DEGAS-RATE.GGGGG	/cp/	Degassing rate of Gas Source GGGGG (kg/s)
HS-DEGAS-STEELM-GGGGG	/p/	Steel mass melted during the system cycle for steel degassing source GGGGG (kg)
HS-DEGAS-CSTEELM-GGGGG	/p/	Cumulative mass of steel melted for steel degassing source GGGGG (kg)
HS-DELE-ATMS-L.CCCCC	/cp/	Integrated energy transfer to boundary volume atmosphere of left (inside) boundary surface of Heat Structure CCCCC due to mass transfer (J)
HS-DELE-ATMS-R.CCCCC	/cp/	Integrated energy transfer to boundary volume atmosphere of right (outside) boundary surface of Heat Structure CCCCC due to mass transfer (J)
HS-DELE-POOL-L.CCCCC	/cp/	Integrated energy transfer to boundary volume pool of left (inside) boundary surface of Heat Structure CCCCC due to mass transfer (J)
HS-DELE-POOL-R.CCCCC	/cp/	Integrated energy transfer to boundary volume pool of right (outside) boundary surface of Heat Structure CCCCC due to mass transfer (J)
HS-FILM-TEMP-L.CCCCC	/cp/	Temperature of film/atmosphere interface at left boundary surface of Heat Structure CCCCC (K)
HS-FILM-TEMP-R.CCCCC	/cp/	Temperature of film/atmosphere interface at right boundary surface of Heat Structure CCCCC (K)
HS-DELM-DROP-L.CCCCC	/cp/	Integrated droplet (fog) mass transfer to boundary volume atmosphere of left (inside) boundary surface of Heat Structure CCCCC (kg)
HS-DELM-DROP-R.CCCCC	/cp/	Integrated droplet (fog) mass transfer to boundary volume atmosphere of right (outside) boundary surface of Heat Structure CCCCC (kg)

HS-DELM-POOL-L.CCCCC	/cp/	Integrated water mass transfer to boundary volume pool of left (inside) boundary surface of Heat Structure CCCCC (kg)
HS-DELM-POOL-R.CCCCC	/cp/	Integrated water mass transfer to boundary volume pool of right (outside) boundary surface of Heat Structure CCCCC (kg)
HS-DELM-STEAM-L.CCCCC	/cp/	Integrated vapor (steam) mass transfer to boundary volume atmosphere of left (inside) boundary surface of Heat Structure CCCCC (kg)
HS-DELM-STEAM-R.CCCCC	/cp/	Integrated vapor (steam) mass transfer to boundary volume atmosphere of right (outside) boundary surface of Heat Structure CCCCC (kg)
HS-ENERGY-FLUX-L.CCCCC	/p/	Energy flux associated with HS-MASS-FLUX-L.CCCCC (W/m^2)
HS-ENERGY-FLUX-R.CCCCC	/p/	Energy flux associated with HS-MASS-FLUX-R.CCCCC (W/m^2)
HS-ENERGY-INPUT.CCCCC	/cp/	Energy input to Heat Structure CCCCC by internal and surface power sources and by other packages (J)
HS-ENERGY-STORED.CCCCC	/p/	Stored energy of Heat Structure CCCCC (J)
HS-FILM-ENTH-L.CCCCC	/p/	Specific enthalpy of liquid film on left (inside) boundary surface of Heat Structure CCCCC (J/kg)
HS-FILM-ENTH-R.CCCCC	/p/	Specific enthalpy of liquid film on right (outside) boundary surface of Heat Structure CCCCC (J/kg)
HS-FILM-MASS-L.CCCCC	/p/	Mass of liquid film on left (inside) boundary surface of Heat Structure CCCCC (kg)

HS-FILM-MASS-R.CCCCC	/p/	Mass of liquid film on right (outside) boundary surface of Heat Structure CCCCC (kg)
HS-FILM-THICK-L.CCCCC	/p/	Thickness of liquid film on left (inside) boundary surface of Heat Structure CCCCC (m)
HS-FILM-THICK-R.CCCCC	/p/	Thickness of liquid film on right (outside) boundary surface of Heat Structure CCCCC (m)
HS-HTC-ATMS-L.CCCCC	/cp/	Atmosphere heat transfer coefficient at left (inside) boundary surface of Heat Structure CCCCC ($W/m^2 \cdot K$)
HS-HTC-ATMS-R.CCCCC	/cp/	Atmosphere heat transfer coefficient at right (outside) boundary surface of Heat Structure CCCCC ($W/m^2 \cdot K$)
HS-HTC-POOL-L.CCCCC	/cp/	Pool heat transfer coefficient at left (inside) boundary surface of Heat Structure CCCCC ($W/m^2 \cdot K$)
HS-HTC-POOL-R.CCCCC	/cp/	Pool heat transfer coefficient at right (outside) boundary surface of Heat Structure CCCCC ($W/m^2 \cdot K$)
HS-ITER-FREQ	/p/	Average iteration frequency over all heat structures
HS-MASS-FLUX-L.CCCCC	/cp/	Mass flux to left (inside) boundary surface of Heat Structure CCCCC ($kg/m^2 \cdot s$)
HS-MASS-FLUX-R.CCCCC	/cp/	Mass flux to right (outside) boundary surface of Heat Structure CCCCC ($kg/m^2 \cdot s$)
HS-MTC-L.CCCCC	/p/	Diffusion mass transfer coefficient at left (inside) boundary surface of Heat Structure CCCCC (m/s)
HS-MTC-R.CCCCC	/p/	Diffusion mass transfer coefficient at right (outside) boundary surface of Heat Structure CCCCC (m/s)

HS-POOL-FRAC-L.CCCCC	/cp/	Fraction left (inside) boundary surface of Heat Structure CCCCC in pool of its boundary volume
HS-POOL-FRAC-R.CCCCC	/cp/	Fraction of right (outside) boundary surface of Heat Structure CCCCC in pool of its boundary volume
HS-QFLUX-ATMS-L.CCCCC	/cp/	Heat flux to atmosphere at left (inside) boundary surface of Heat Structure CCCCC (W/m^2)
HS-QFLUX-ATMS-R.CCCCC	/cp/	Heat flux to atmosphere at right (outside) boundary surface of Heat Structure CCCCC (W/m^2)
HS-QFLUX-POOL-L.CCCCC	/cp/	Heat flux to pool at left (inside) boundary surface of Heat Structure CCCCC (W/m^2)
HS-QFLUX-POOL-R.CCCCC	/cp/	Heat flux to pool at right (outside) boundary surface of Heat Structure CCCCC (W/m^2)
HS-QTOTAL-ATMS-L.CCCCC	/p/	Time and surface integral of heat flux to atmosphere at left (inside) boundary surface of Heat Structure CCCCC (J)
HS-QTOTAL-ATMS-R.CCCCC	/p/	Time and surface integral of heat flux to atmosphere at right (outside) boundary surface of Heat Structure CCCCC (J)
HS-QTOTAL-POOL-L.CCCCC	/p/	Time and surface integral of heat flux to pool at left (inside) boundary surface of Heat Structure CCCCC (J)
HS-QTOTAL-POOL-R.CCCCC	/p/	Time and surface integral of heat flux to pool at right (outside) boundary surface of Heat Structure CCCCC (J)
HS-TEMP.CCCCCMN	/cp/	Temperature at node MN of Heat Structure CCCCCC (K)

5. Example Input

This section provides example input for a problem which uses the Heat Structure package for MELGEN and MELCOR execution. This problem is included to provide a nontrivial example of the input for the HS package and is not intended to be a reactor safety application of the MELCOR Code System.

Consider a boiling water reactor (BWR) with a Mark II containment. The reactor produces 3226 MW thermal power from 47,368 nuclear fuel rods. The example problem whose input is discussed here is a boil-off with the core initially 85% covered. The following packages are used in this calculation:

(1) Heat Structure Package

(2) Control Volume Hydrodynamics Package

(3) Flow Path Package

(4) Material Properties Package

(5) Control Function Package

(6) Tabular Function Package

This example problem does not use the Core package. The core is represented by a single fuel rod heat structure with multiplicity 47,368. The following sections contain illustrations of input for this problem.

5.1 Example MELGEN Input

A subset of the MELGEN input that will create a restart file to execute the boil-off problem is given here. This input contains records not only for heat structures but also for some concomitant gas source, noncondensible gas, material properties, and tabular function input.

5.1.1 Heat Structure Input

The following illustrates complete input records for 3 of 21 heat structures in the example problem. These provide examples of various nodalizations, material composition, geometries, power sources, and boundary conditions for heat structures. Refer to Section 2.1.1 for details on MELGEN heat structure inputs.

The following records are comments (records beginning with the symbol*) and a complete set of input for an intact fuel rod in the LaSalle nuclear reactor. This heat structure is a

vertical structure with a cylindrical geometry. It has a multiplicity equal to the number of fuel rods in the core. There are 12 temperature nodes. Each fuel rod is composed of uranium dioxide fuel, a helium gap, and a Zircaloy cladding. The decay-heat power after scram is represented by an internal power source whose power is given as a function of time by a tabular function. A symmetry boundary condition is applied at the center and a convective boundary condition for external flow with calculated heat transfer coefficient is applied at the surface.

```
*INTACT FUEL RODS (5.4943-9.3043 M) - HEAT TRANSFER TO CORE
HS10100000  12          2
HS10100001  'FUEL ROD'
HS10100002  5.4943      1.0
HS10100003  4.7368E4
HS10100100  -1          1       0.0
HS10100102  8.678160E-4         2
HS10100103  1.735632E-3         3
HS10100104  2.603448E-3         4
HS10100105  3.471264E-3         5
HS10100106  4.339080E-3         6
HS10100107  5.206896E-3         7
HS10100108  5.321196E-3         8
HS10100109  5.524421E-3         9
HS10100110  5.727646E-3         10
HS10100111  5.930871E-3         11
HS10100112  6.134096E-3         12
HS10100201  uranium-dioxide     6
HS10100202  helium              7
HS10100203  zircaloy            11
HS10100300  500     -1 2.0889E-5
HS10100301  1.0     6
HS10100302  0.0     11
HS10100400  0
HS10100600  1       101     EXT     0.5     0.5
HS10100601  .5      EQUIV-BAND      .1
HS10100700  1.429449E-1 1.226819E-2     3.70884
```

The following records are comments and a complete set of input for the upper head of the pressure vessel for the reactor. The upper head has a hemispherical geometry and is made of carbon steel. A convective boundary condition for internal flow with calculated heat transfer coefficients is applied at the interior surface of the reactor and a convective boundary condition with heat transfer coefficient that is obtained from a tabular function is applied at the exterior surface. The exterior surface boundary condition represents the insulation on the pressure vessel.

```
* UPPER HEAD - UPPER PLENIUM TO DRYWELL HEAT TRANSFER
*
HS10402000  5       5       -1
```

```
HS10402001  'UPPER HEAD'
HS10402002  18.53
HS10402100  -1      1     3.226
HS10402101  3.334   5
HS10402200  -1
HS10402201  CARBON-STEEL  4
HS10402300  -1
HS10402400  1       104   INT     0.5     0.5
HS10402401  .75     EQUIV-BAND    3.
HS10402500  50.59   3.226 3.226
HS10402600  5120    205   EXT     0.5     0.5
HS10402601  .3      EQUIV-BAND    15.
HS10402700  54.55   3.334 3.334
HS10402800  -1
HS10402801  560.0   5
```

The following records are comments and a complete set of input for the wetwell floor of the containment for the nuclear power plant. It is represented as a rectangular, horizontal heat structure which is made of concrete. At both surfaces a convective boundary condition with calculated heat transfer coefficient is applied.

```
* WETWELL FLOOR
* WETWELL TO SECONDARY CONTAINMENT HEAT TRANSFER
HS20002000  5         1             -1
HS20002001  'WETWELL FLOOR'
HS20002002  -28.7274 0.0
HS20002100  -1        2             0.0
HS20002101  0.7620    4
HS20002200  -1
HS20002201  CONCRETE 4
HS20002300  -1
HS20002400  1     300   EXT         0.5     0.5
HS20002401  .8    EQUIV-BAND        15.
HS20002500  548.0    26.416      26.416
HS20002600  1     200  'EXT'       0.5     0.5
HS20002601  .8    EQUIV-BAND        18.
HS20002700  548.0 26.416          26.416
HS20002800  -1
HS20002801  325.0 5
```

5.1.2 Gas Source Input

The following records are a complete set for a gas source which models the degassing of limestone concrete by the release of free water. Refer to Section 2.1.2 for details on MELGEN gas source input.

The source releases water vapor into the boundary volume of the left boundary surface of Heat Structure 20001 between the temperatures 360 K and 380 K. It is distributed over the entire heat structure and can release as much as 2.211×10^5 kg of water vapor.

```
HSDG200110  -20001     4          H2O-VAP
HSDG200111  110.0      1.808E6    360.0       380.0
```

Limestone concrete can also release water vapor from bound water and carbon dioxide from calcium carbonate as its temperature increases. The following records are input for the HS package degassing model for gas sources for the degassing of the concrete in Heat Structure 20001.

```
HSDG200120  -20001     4   CO2
HSDG200121  72.0       6.912E6    500.0        520.0
HSDG200130  -20001     4   H20-VAP
HSDG200131  110.0      2.909E7    360.0        380.0
```

5.1.3 Noncondensible Gas (NCG) Input

The following records specify the noncondensible gases for the example problem. The carbon dioxide specification must be present since it is released by a gas source for the degassing model. The water vapor which is released by some gas sources is a material that is present in all problems. Refer to the NCG Package Users' Guide for details on NCG MELGEN input.

```
NCG004  H2     4  *  HYDROGEN
NCG005  N2     5  *  NITROGEN
NCG006  CO2    6  *  CARBON DIOXIDE
```

5.1.4 Material Property (MP) Input

The following records illustrate the material properties input which is required for the new material 'CONCRETE'. For this problem, input for the new materials carbon steel and helium must also be present. Tabular functions 106, 107, and 108 must also be provided for the thermal conductivity, heat capacity, and density of concrete. Refer to the MP Package Users' Guide for details on MP MELGEN input.

```
MPMAT10600  CONCRETE
MPMAT10601  THC 106
MPMAT10602  CPS 107
MPAT10603   RHO 108
```

5.1.5 Tabular Function (TF) Input

The following records are input for Tabular Function 120, which is the heat transfer coefficient as a function of temperature for the insulated exterior of the reactor pressure

vessel. This function specifies a constant heat transfer coefficient of 10 W/m^2 • K. Refer to the TF Package Users' Guide for details on TF MELGEN input.

```
TF12000  'HTC OUT VESS'      2          1.0       0.0
TF12010  273.15   10.0       5000.0    10.0
```

The following records are input for Tabular Function 500, which is the decay-heat power as a function of time for the LaSalle reactor core. This function specifies an initial power of 3326 MW with a decay that is typical of a BWR core after scram.

```
TF50000     'DECAY-HEAT POWER'    22   3.326E9    0.0
TF50011  0.0  1.000000  0.1  0.900689
TF50012  0.2  0.274300   0.3  0.153171
TF50013  0.4  0.110821   0.5  0.091625
TF50014  0.6  0.083212   0.8  0.073556
TF50015  1.0  0.064777   1.5  0.063089
TF50016  2.0  0.059854   3.0  0.057265
TF50017  4.0  0.055204   6.0  0.052085
TF50018  8.0  0.049776   10.0  0.047947
TF50019  15.0  0.044575   20.0  0.042176
TF50020  30.0  0.038783   40.0  0.036348
TF50021  60.0  0.031546   1.0E5  0.001460
```

5.2 Example MELGEN Input for Ice Condenser Model

An example of heat structure, gas source and tabular value input that was used to model a PWR ice condenser is provided below. See the description related to input Record HSCCCCC600 for details.

```
HS00500000  2  2  -1  *  two nodes
HS00500001  'Ice Condenser'      * name of structure
HS00500002  10.0  1.0     * elevation is vertical
HS00500003  1000.    * multiplicity
HS00500100  -1 1  0.0  * node data
HS00500101  0.15  2   * location node 2
HS00500200  -1     * index for material
HS00500201  basket 1   * mat. name and mesh interval
HS00500300  0    * no internal heat source
HS00500400  0    * adiabatic left surface
HS00500600  1    1  ice  0.5  0.5  * convective H.T.C.
HS00500700  1.0  0.3  14.60  * CLNR is diameter
HS00500800  -1    * input option parameter
HS00500801  274. 2   * initial temperature
*
HSDG000010  500   1     pool * ice water to pool
HSDG000011  1000. 754419.  274.  373.  1.2  0.33  1.
*
```

```
* basket properties
*
MPMAT01200 basket
MPMAT01201 rho 300
MPMAT01202 cps 400
MPMAT01203 thc 500
*
TF30000   'basket rho'  1  1.0
TF30010   274.  1.
TF40000   'basket cps'  1  1.0
TF40010   274.  485.7
TF50000   'basket thc'  1  1.0
TF50010   274.  5.
*
```

5.3 Example MELGEN and MELCOR Input for Film-Tracking Model

An example of heat structure, film-tracking, tabular function, spray and transfer process input that was used to model a passive containment cooling system for a hypothetical containment dome is provided below. See the film-tracking input described in Sections 2.1.3 and 2.2.3 for details.

The MELGEN input for the film-tracking model is as follows:

```
cv00100  'containment'  2  2  7
cv001a1  pvo1  1.0e5  tatm 348.  rhum  1.0  mlfr.4  1.0
cv001b1  0.0    0.0  6.0   169.646  9.0    226.195
cv001c1  ae   100  2
*
cv00200  'environment'  2  2  6
cv002a1  pvo1  1.0e5  tatm 298.  rhum  0.5  mlfr.4  1.0
cv002b1  0.0    0.0  48.0   1.e10
*
tf10000  'enthalpy source' 4  1.0   * simulates containment heating
tf10010  0.0  0.0 10.  0.0 10.1  1.0e7  1.e4 1.0e7
*
hs00100000      2 2                   *  2 nodes
hs00100001      'bot. cyl.'           *  cyl. bottom section
hs00100002      0.0  1.0              *  elevation, vertical
hs00100003      1.                    *  multiplicity
hs00100100      -1  1  3.             *  temp and node, loc.
hs00100101      3.05  2               *  location node 2
hs00100200      -1                    *  index for material
hs00100201      'stainless-steel'  1  *  material, mesh loc.
hs00100300      0                     *  no internal power
hs00100400      1  1  int  0.5  0.5   *  convective h.t.c.
hs00100500      1.  3.e-0 3.0         *  clnl is radius
```

```
hs00100600      1  2  ext 0.5   0.5   *  convective h.t.c.
hs00100700      1.  3.e-0 3.0          *  clnl is radius
*
hs00200000      2  2                   *  2 nodes
hs00200001      'mid. cyl.'            *  cyl. middle section
hs00200002      3.0  1.0               *  elevation, vertical
hs00200003      1.                     *  multiplicity
hs00200100      -1  1  3.              *  temp and node, loc.
hs00200101      3.05  2                *  location node 2
hs00200200      -1                     *  index for material
hs00200201      'stainless-steel'  1   *  material, mesh loc.
hs00200300      0                      *  no internal power
hs00200400      1  1  int  0.5  0.5    *  convective h.t.c.
hs00200500      1.  3.e-0 3.0          *  clnl is radius
hs00200600      1  2  ext 0.5   0.5    *  convective h.t.c.
hs00200700      1   3.e-0 3.0          *  clnl is radius
*
hs00300000      2  5                   *  2 nodes
hs00300001      'top hemi.'            *  hemispherical dome
hs00300002      6.0  1.0               *  elevation, vert. (unused)
hs00300003      1.                     *  multiplicity
hs00300100      -1  1  3.              *  temp and node, loc.
hs00300101      3.05  2                *  location node 2
hs00300200      -1                     *  index for material
hs00300201      'stainless-steel'  1   *  material, mesh loc.
hs00300300      0                      *  no internal power
hs00300400      1  1  int  0.5  0.5    *  convective h.t.c.
hs00300500      1.  3.e-0 3.0          *  clnl is radius
hs00300600      1  2  ext 0.5   0.5    *  convective h.t.c.
hs00300700      1.  3.e-0 3.0          *  clnl is radius
*
hsft00000       3
hsft00100       300  1   0.5  100  0.0  0  0  0  10  20
hsft00101       200  0.5 1.0
hsft00200       200  1   0.0  0    0.0  0
hsft00201       100  1.0 1.0
hsft00300       100  0   0.0  0    0.0  0
*
tf01000  'water source' 3 1.0          *  passive containment cooling
tf01010  0.0  3.e0  1.5e3  3.e0  4.e3  7.0
*
tf02000  'water enthalpy'  2  1.0      *  water at about 300 K
tf02010  0.0  1.e5  1.e4   1.e5
*
sprsr0100 'rain'  1  8.                *  rain from HS 300
sprsr0101 300     0. -1  -1  100       *  "out" Trans. Pr. 100
sprsr0102 3.e-3   1.                   *  drop size (3 mm)
```

```
*
tpin10000 1  1                          *  water mass, temp.
tpot10000 1  100  def.1                 *  from "in" TP 100
*
```

The MELCOR input (to change the drainage partitioning on the left surface of structure 300) is as follows:

```
*
hsft00000       1
hsft00100       300  1   0.2 100 0.0 0 *  dec. left rain
hsft00101       200  0.8 1.0            *  inc. left
*
```

6. Example Output

Both time-independent and time-dependent data from the data base for the Heat Structure package are printed during MELGEN and MELCOR execution. Sections 6.1 and 6.2 discuss the printed output from these data, respectively. Additional information is printed during MELGEN and MELCOR execution. The output containing this information is discussed in Sections 6.3 and 6.4.

6.1 Time-independent Data Output

During MELGEN execution after all input data are processed and all initialization calculations are completed and during MELCOR execution prior to commencing the first cycle of a restart, time-independent data are printed. For the HS package, this output follows the header:

EDIT FOR HEAT STRUCTURE PACKAGE
(TIME-INDEPENDENT DATA)

For Heat Structure CCCCC with user input name HSNAME, the following information is printed in the section "HEAT STRUCTURE CCCCC HSNAME":

(1) number of temperature nodes

(2) location of temperature nodes

(3) geometry type

(4) altitude of base

(5) orientation parameter

(6) multiplicity

(7) name of material in each mesh interval

(8) mass in each mesh interval

(9) total mass of structure

(10) volume in each mesh interval

(11) total volume of structure

(12) internal power source information (tabular function number for power table if source exists or statement that no internal power source exists)

(13) power fractions for each mesh interval if an internal power source exists or statement that all power fractions are zero if no internal power source exists

(14) boundary volume numerical identifier for each boundary surface

(15) type of boundary condition which is applied at each boundary surface

(16) type of flow (internal/external) over each boundary surface

(17) surface power source information for each boundary surface (tabular function number for power table if source exists or statement that no surface power source exists)

(18) statement indicating whether or not mass transfer calculations are performed for each boundary surface

(19) area of each boundary surface

(20) characteristic length of each boundary surface

(21) axial length of each boundary surface

(22) critical pool fractions for pool and atmosphere heat transfer

At each boundary surface whose critical pool fraction for pool heat transfer exceeds its fraction for atmosphere heat transfer, heat transfer to neither the pool nor atmosphere will be calculated for pool fractions between these values. If at least one surface has such a specification, information is printed for each such surface in the section which follows the statement,

> WARNING – HEAT TRANSFER MAY NOT BE CALCULATED AT THE FOLLOWING SURFACES:

This information includes the following:

(1) identification number of heat structure,

(2) side of the heat structure – left (inside) or right (outside) – for which no heat transfer might be calculated, and

(3) range of pool fraction for which no heat transfer will be calculated.

If no gas sources for the HS package degassing model are present the statement

NO GAS SOURCES FOR THE DEGASSING MODEL ARE PRESENT IN THIS PROBLEM

Is printed. If Gas Source CCCCC exists for a problem, the following information is printed in the section "GAS SOURCE CCCCC":

(1) mesh intervals over which source is distributed

(2) name of gas which is released and number of control volume into which it is released

(3) density

(4) heat of reaction

(5) boundaries of temperature range over which gas is released

(6) total mass of gas that can be released

The following is an example of the kind of time-independent output obtained when the film-tracking model is active (there is no time-dependent output from the model):

6.2 Time-Dependent Data Output

During MELGEN execution after all input data are processed and all initialization calculations are completed and during MELCOR execution at user specified time intervals, time-dependent data are printed. For the HS package, this output follows the header:

EDIT FOR HEAT STRUCTURE PACKAGE
(TIME-DEPENDENT DATA)
TIME = 0.000E+00 CYCLE = 000000000

The version number and creation date of the HS package and its associated manuals are printed at the top of the page containing this header. The units for each output quantity are given following this header.

The output for the heat structures is printed in the following four sections:

(1) HEAT STRUCTURE TEMPERATURE DISTRIBUTIONS

(2) HEAT TRANSFER DATA

(3) MASS TRANSFER DATA

(4) ENERGY TRANSFER DATA

The temperature at each node in each heat structure is printed in the section "HEAT STRUCTURE TEMPERATURE DISTRIBUTIONS". The temperatures for Heat Structure CCCCC with name HSNAME are printed on lines following a left justified "HEAT STRUCTURE CCCCC HSNAME".

The following data for the boundary surfaces of each heat structure are printed in the section "HEAT TRANSFER DATA":

(1) boundary volume

(2) surface temperature

(3) pool fraction (fraction of surface in pool of its boundary volume)

(4) atmosphere convective heat transfer coefficient

(5) atmosphere radiation heat transfer coefficient

(6) pool heat transfer coefficient

(7) atmosphere heat transfer flow regime

(8) pool heat transfer flow regime

The following data for each boundary surface of each heat structure are printed in the section "MASS TRANSFER DATA":

(1) boundary volume

(2) pool fraction

(3) mass flux

(4) liquid film thickness

(5) liquid film mass

(6) changes in mass of steam, fog droplets, and pool in boundary volume due to mass transfer at the surface

The following data for each heat structure are printed in the section "ENERGY TRANSFER DATA":

(1) stored energy

(2) energy input by internal and surface power sources and by transfers from other packages

The following data are printed in this section for each boundary surface:

(3) specific enthalpy of its liquid film

(4) time and surface integral of its atmosphere and pool heat fluxes

(5) energy transferred to atmosphere and pool of its boundary volume due to mass transfer

The information printed in this section at different times is sufficient to establish the global conservation of energy for the HS package.

If gas sources are present in the problem, the following data are printed for each gas source in the section "DEGASSING SOURCE DATA":

(1) number of heat structure which contains source

(2) control volume into which gas is released

(3) degassing rate

(4) total mass of gas released

(5) total energy consumed by gas release

An example of the time-independent edit obtained when the film-tracking model is active follows:

```
********** FILM-TRACKING MODEL SETUP **********

THE FIRST SET OF STRUCTURES COUPLED FOR PURPOSES
OF FILM TRACKING CONSISTS OF 3 STRUCTURES:
```

```
1 - STRUCTURE  300
RECEIVES WATER ON THE RIGHT (OUTSIDE) SURFACE VIA:
MASS SOURCE TABULAR FUNCTION  10
AND ENTHALPY SOURCE TABULAR FUNCTION  20
DRAINAGE FROM THE LEFT SIDE IS PARTITIONED AS FOLLOWS:
RAIN TO TRANSFER PROC.  100  = 5.0000E-01
TO HEAT STRUCTURE  200       = 5.0000E-01
DRAINAGE FROM THE RIGHT SIDE IS PARTITIONED AS FOLLOWS:
TO HEAT STRUCTURE  200       = 1.0000E+00

2 - STRUCTURE  200
DRAINAGE FROM THE LEFT SIDE IS PARTITIONED AS FOLLOWS:
TO HEAT STRUCTURE  100       = 1.0000E+00
DRAINAGE FROM THE RIGHT SIDE IS PARTITIONED AS FOLLOWS:
TO HEAT STRUCTURE  100       = 1.0000E+00

3 - STRUCTURE  100
DRAINAGE FROM THE LEFT SIDE IS PARTITIONED AS FOLLOWS:
TO POOL OF CONTROL VOL     1 = 1.0000E+00
DRAINAGE FROM THE RIGHT SIDE IS PARTITIONED AS FOLLOWS:
TO POOL OF CONTROL VOL     2 = 1.0000E+00
```

6.3 Additional MELGEN Output

Prior to the time-independent data edit, the following information is given for the HS package during MELGEN execution:

(1) number of input errors detected during processing of input records which are internal to the HS package (pass-one processing),

(2) total number of heat structures and gas sources

(3) data-base memory requirements for the HS package

(4) CPU time which was required for pass-one input processing

(5) scratch memory requirements for the HS package

(6) number of input errors detected which result from inconsistencies with other packages (pass-two processing)

(7) number of iterations which were required for steady-state temperature convergence for each heat structure whose input requested steady-state initialization

6.4 Additional MELCOR Output

Additional MELCOR output which is provided by the HS package is discussed in this section.

Each edit includes the section "HEAT STRUCTURE PACKAGE STATISTICS" which documents the performance of the HS package. For the entire problem and for the portion of the problem between the past and present edits, the following information is printed:

(1) CPU time for calculation, edit, and restart

(2) average iteration frequency per heat structure

7. Diagnostics and Error Messages

The Heat Structure package prints a message if any of the following occur:

(1) an error is detected during MELGEN input processing

(2) temperature convergence during steady-state initialization in MELGEN execution is not achieved

(3) an error is detected during MELCOR input processing

(4) during MELCOR execution the HS package requests repeating a computational cycle with a reduced timestep

The messages are discussed in Section 7.1 through 7.3.

7.1 MELGEN input Errors

Error messages are printed by the HS package when errors are detected during input processing in MELGEN execution. Such errors occur if input specifications are violated or if input data are inconsistent. In general any input which violates a "must" imperative in the user input descriptions of Sections 2.1.1 and 2.1.2 will be detected as an error. All such error messages are self-explanatory and indicate the input record which must be corrected. Error messages are also printed if materials, control volumes, or tabular functions which are specified in heat structure input are not present in a problem. Concomitant with the detection of an error during MELGEN input processing is a directive to not create a restart file.

Failure to converge in a steady-state initialization temperature iteration usually indicates a problem associated with the user inputs related to the heat structure nodalization or CVH boundary volume. In this case the user should re-examine the input for errors or unrealistic

conditions. As a last resort, the user can abandon steady-state initialization for that heat structure and prescribe a temperature profile with the HSCCCCC800 and HSCCCCC801 input records.

7.2 MELCOR Input Errors

Error messages are printed by the HS package when errors are detected during input processing in MELCOR execution. All such error messages are self-explanatory and indicate the input record which must be corrected. Error messages are also printed if materials, control volumes or tabular functions which are specified in heat structure input are not present in a problem. Concomitant with any input error message during MELCOR execution is a directive to not proceed with a transient calculation.

7.3 Requests to Repeat a Computational Cycle

The HS package prints a diagnostics message during MELCOR execution whenever it requests repeating a computational cycle with a reduced timestep because of numerical difficulties. MELCOR only terminates execution after a time-step reduction if the new time-step is less than the minimum specified by the user. In such a situation, a restart file is written and an edit of all current data is performed.